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A TYPE OF LANDSLIDE COMMON IN WEST VIRGINIA

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LANDSLIDES AND THEIR RELATION TO HIGHWAYS

A REPORT OF OBSERVATIONS MADE IN WEST VIRGINIA AND OHIO TO DETERMINE THE CAUSE OF SLIDES AND DEVISE MEANS OF CONTROL

Reported by GEORGE E. LADD, Associate Economic Geologist, United States Bureau of Public Roads

PART 1

This, the first of two articles which will deal with the causes and control of landslides in West Virginia and Ohio, is devoted to the geological characteristics of the region and the causes of slides. A subsequent article will deal more particularly with the engineering problems involved and the various methods of control which have been tried, illustrated by reference to a number of specific cases of slides. Physical analyses of materials and the results of laboratory soil tests might properly be included in this first article, but their presentation has been deferred in expectation that it will be possible to treat this phase of the subject more adequately after the completion of work now in progress.

THE geological formations and topography of a large part of West Virginia and Ohio are responsible for two sets of economic conditions—one good, the other bad, of which, fortunately, the good far outweigh the bad. The formations themselves contain abundant supplies of coal, oil, and natural gas, and of clays and shales suitable for the manufacture of a great variety of products. The peculiar topography developed in them furnishes an immense potential water supply and great reaches of navigable streams. Together these constitute a tremendous natural endowment of great value and economic importance.

FIG. 1.—DAMAGE TO A HIGHWAY BY A LANDSLIDE RESULTING IN SUBSIDENCE, UPHEAVAL, AND LATERAL DISLOCATION

LANDSLIDES A SERIOUS ROAD PROBLEM

To the road builder, however, these same formations and the resulting topography present a problem which, not yet solved, makes road construction and maintenance both difficult and expensive, particularly in West Virginia. In the latter State valleys are narrow and deep and there are no compensating extended ridges. Roads are, therefore, confined to the valleys in many of which the best locations are already occupied by railroads. As a result the roads are necessarily winding and nearly always up and down hill, road mileage between points is increased and construction is difficult. But the most serious of the obstacles which nature has placed in the path of the road builder to solve result from landslides for the frequent occurrence of which the geological formations and considerable annual rainfall are responsible.

Such slides cost these States annually a million dollars or more in extra construction work and maintenance of roads. (Figs. 1 and 2.) They also cause great annual expense to railroads and, in a lesser degree, to power, telephone, telegraph, gas, oil, and water-supply companies. Occasionally they damage a residence or a cemetery, and to some extent farm and grazing land.

Roads are affected in various ways. The slides may merely fall upon them and leave several thousand cubic yards of detritus to be removed. They may be dislocated or thrown out of line by the impact of the sliding material. The whole mass of material above, immediately beneath, and beyond and below the road may move, covering, dislocating, breaking and upheaving, or sinking the road. Any one or more of these, which may be called natural movements, may take place at a single locality. Yet, in their combined effects, these movements of material from a natural position are not more destructive, perhaps less so, than the movements of artificially placed fill material which carry away the shoulders of the roads and undermine the pavement back to the solid shale or sandstone. Conditions under which such movements occur are illustrated in Figure 3.

FIG. 2.—IN SOME LOCATIONS THERE IS A CONTINUOUS FALL OF MATERIAL UPON THE HIGHWAY AND IT IS PARTICULARLY HEAVY IN THE WINTER AND SPRING MONTHS

GEOLOGY OF AREA STUDIED

The area affected by slides, as shown on the map, Figure 4, includes the eastern and southeastern portions of Ohio where very many occur, and, roughly, the western half of West Virginia, with local regions, lying mostly in Mineral and Grant Counties, where slides are frequent. Slides also occur in scattered localities throughout the southern tier of counties in Ohio.

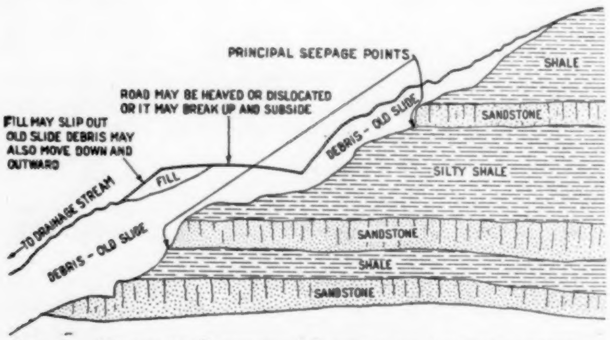

Fig. 3.—Diagram Showing Manner of Accumulation of Detritus, Succession of Sandstone and Shale Beds and Natural Seepage Planes. The Road Rests Entirely on Material Which is Not Permanently Stable

The area lies at the southern limit of, and almost entirely beyond the influence of the ice invasions of the glacial period in a great geosynclinal trough or elongated bowl, the axis of which begins in Greene County, Pa., and extends southwesterly into Kentucky. In this great trough the Pennsylvanian or Upper Carboniferous formations have been preserved from erosion. These formations include the Monongahela, Conemaugh,

Fig. 4.—Outline Map Showing by Shaded Portion the Area in Which Landslides are of Common Occurrence

Pottsville, and Allegheny series, and it is in these, particularly in the Monongahela and Conemaugh, that a large percentage of the slides in both States occur. To a much less extent the base of the Permian (Dunkard) formations also furnishes materials for slides, and along the southern border of western Ohio occasional slides occur in the Niagara series of Silurian age, and the Maysville of Ordovician age. The latter are con-

Fig. 5.—Typical Bed of Shale with Intercalated Layers of Sandstone

fined to localities where very pure, "fat" clay shales have had an opportunity to become water-soaked.

Within this area where landslides are so common the geological formations consist of alternating strata of sandstones and shales, with occasional beds of hard, compact, so-called fire clay, and, in some localities, thin beds of siliceous limestone. Associated with these are numerous beds of coal.

The standstone strata are traversed by numerous joint planes or fractures. They vary greatly in continuity, and rapidly in thickness. Frequently, and often abruptly, they become finer in grain until there is complete transition into shale. As a rule, the grains are not thoroughly cemented together and generally they exhibit a lack of toughness which makes them unsuitable for use as a road material.

The shales particularly in West Virginia are characteristically siliceous, even the purest of them containing enough silt to make them slightly gritty. They also contain varying amounts of lime and iron, often a great deal of both. As a general rule the beds are more massive and less broken than the sandstone strata, though they commonly contain thin layers of sandstone. The sandstones, on the contrary, are often split up into many thin beds separated by shale seams. (Figs. 5 and 6.)

Lying within the great geosyclinal trough previously referred to, these alternating beds of shale and sandstone dip generally toward the axis of the trough, but the major sycline is broken by minor folds so that there are numerous local anticlines and synclines.

In the portion of the area which lies in West Virginia the hills range from 100 to 2,300 feet in height. All are characterized by marked sharpness of slope. In eastern Ohio, except in the territory immediately adjacent to the Ohio River, the hills are lower and more gently rounded, and the deep narrow valleys of western West Virginia are largely absent.

These conditions, the nature and composition of the two principal rock materials; the vertical joints in the sandstone layers; the massive and impervious character of most of the shales; the dip of the strata (even though very slight); the characteristic topography of the region; and the abundant rainfall, averaging 43 inches a year; all have a direct bearing on the occurrence and character of the landslides in the two States, of which there are four principal types involving material in its original or natural position.

LANDSLIDES CLASSIFIED

The great majority of the slides are flow movements, either creeping or sudden, of the detritus which mantles the solid rock of the hillsides, and which results mainly from the weathering of the exposed shale surfaces.

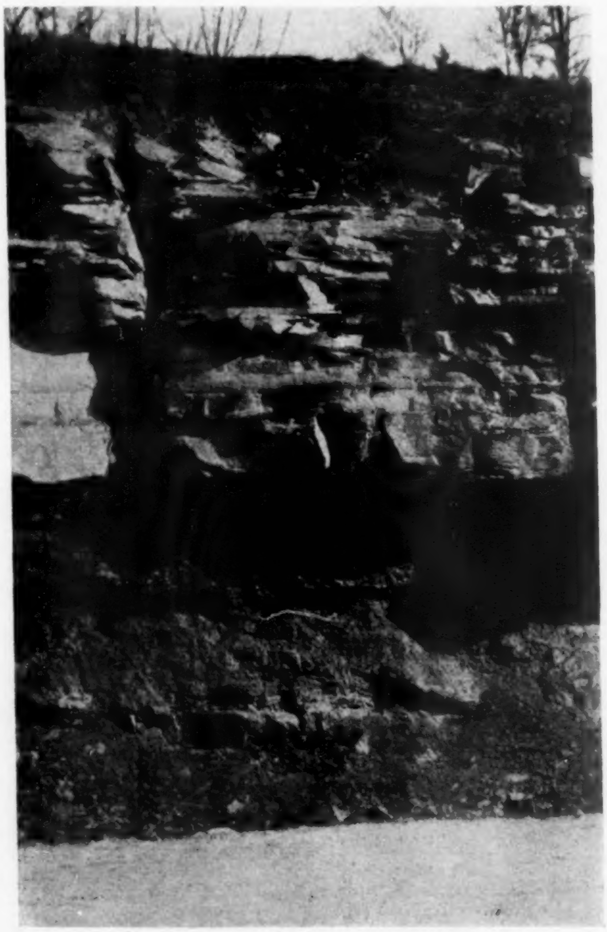

FIG. 6.—BED OF SANDSTONE BEING UNDERMINED BY WEATHERING OF UNDERLYING SHALE. NOTE THE VERTICAL JOINT IN THE SANDSTONE

These are extraordinarily frequent and involve relatively large masses of material. (Fig. 7.)

Second in number, perhaps, and in the seriousness of their effect upon the highways, are those in which superficial weathered rock is precipitated as a matter of slope adjustment, as illustrated in Figure 2. A third class of slide consists of comparatively small-scale adjustments of jointed material where a vertical face results from artificial cut or stream erosion. (Fig. 16.)

Least frequent of all is a fourth class of slide in which the material moved consists of large masses of solid rock. Only one slide of this type has been brought to the writer's attention in Ohio,[1] and only a few have occurred in recent times in West Virginia. The most important of these occurred in Mineral County just south of Cumberland, Md., where a large rock mass

FIG. 7.—A NATURAL LANDSLIDE IN WEST VIRGINIA. THIS IS THE BEGINNING OF A TOPOGRAPHIC BREAK THROUGH THE CREST OF A HILL

went out as a result of a highway cut in stratified rock which dipped sharply toward the road. (Fig. 17.)

In addition to the foregoing classes, all of which involve material in its original or natural position, there is a fifth class which involves the movement of artificially placed highway fill material. Probably more than 50 per cent of the damage to roads and the most serious highway problems in the two States result from slides of this type. (Fig. 22.)

It is apparent from the mere description of these types of slides that they are caused by different combinations of the several geological and topographic conditions previously mentioned, and that no single method will suffice to prevent them. Preventive measures in each case must take account of the manner in which the slide is caused. As a basis for subsequent discussion of possible preventive measures, it will be desirable now to investigate the manner in which each of the classes of slides is caused and determine, in each case, the effect of the several contributing geological and topographic factors.

DETRITAL MASSES LUBRICATED BY CLAY AND ROUNDED SAND

The class of slides which has been described as a flow movement of detrital masses—the predominant type in the area studied—is conditioned by the nature of the material composing the mass and the geologic structure upon which it rests. The detritus consists of sandy clay originating from shale beds and of sand and sandstone fragments and bowlders originating from massive beds of sandstone or from the intercalated sandstone layers often scattered through the shale beds. The sandstones are sufficiently hard strongly to resist

[1] This slide has not been visited by the writer but is quite likely a case of the undermining of a sandstone stratum by weathering influences.

weathering influences, and the shales when continually moist are very resistant to simple erosive influences although they yield to weathering processes because of their predominant clay content. The swelling of the clay when wet and shrinking on drying lead to cracking, curling, and peeling off of thin layers where the shale is exposed to weathering.

FIG. 8.—CHARACTER OF MATERIAL WHICH COMPOSES LANDSLIDE DETRITUS. NOTE ABUNDANCE AND COARSENESS OF SANDSTONE FRAGMENTS

Where the shale-clay is very silty, that is, full of very fine sand or silica particles, ordinary physical disintegration occurs rapidly. Under existing weather conditions such surfaces are alternately wet and dry and there is a continual sloughing off of the exposed shale face. The fine material thus produced falls and accumulates on the slope below. Rain and wind remove this material to some extent and deposit it further down the hill. In this way the shale face recedes as long as it is exposed to weathering influences and consequently it undermines its overlying bed of sandstone. In time the undermined sandstone breaks off and falls, often as enormous bowlders which are subsequently broken up into smaller fragments by freezing of water within minute fractures which penetrate the sandstone mass. The cover-page illustration shows an enormous block of sandstone broken loose from its bed as the result of undermining through the weathering of an underlying shale. It illustrates one of the stages in the production of the mixed detritus which covers the hillsides of this region.

Figure 6 illustrates the retreat of a shale bed and the undermining of its overlying sandstone. In this case the laminations of the sandstone are such as to produce small fragments on falling. Note the vertical joint which permits circulation of water through the sandstone bed and that such water must escape along the top of the underlying, impervious shale bed.

The result of these processes is the accumulation of detrital masses consisting of various mixtures as described above. The proportions of clay, silt, sand, and sandstone in these masses vary considerably, but some clay is practically always present and when wet acts as a lubricant within the mass and is an important factor in producing slides.

On superficial examination many of these masses appear far removed in character from material that could easily become unstable and readily slump or slide. (Figs. 8 and 9.) Wherever surfaces are free from vegetation the material seems to be too rocky and sandy for such behavior, but such surfaces are deceptive. The sandstone fragments, varying from small, angular pebbles to large bowlders, which appear to form a large percentage of the mass, are merely a residue which remains after the removal of the surface clay by rain, and the interior of the mass in which clay remains is different in character.

The shales of West Virginia and the products they form in weathering are so full of silt and fine sand that they are perceptibly gritty, but in Ohio they are more clayey and the further west they occur the n carer do they approach to pure clay.

During the field study it was found that many masses of detritus slumped or slid in spite of the fact that they appeared to contain little clay matter and it was thought that the physical condition of the sand and silt particles might be a factor of importance. A microscopic examination of numerous samples was made and it was found that the sand and silt particles were highly rounded. Thus a quicksand condition was found which accounts in part for the ease of movement of some of these detrital masses when wet. Although the detritus is rich in sandstone fragments and bowlders there still remain in it sufficient lubricating clay and rounded quartz particles to give it a degree of fluidity which leads to landslides even though the water content may be relatively low. It is probably true, especially in West Virginia, that many of the superficial masses

FIG. 9.—TYPICAL APPEARANCE OF LANDSLIDE DETRITUS

which slide would not do so if the large amount of contained sand and silt were sharp and angular.

We have then, on the hillsides of this area, masses of material which become unstable when the moisture content passes a certain critical point which of course depends on the composition of the mass and is therefore variable. The water content not only increases the

lubricating properties of the clay and rounded sand but also adds weight to the mass. The heavy annual rainfall is sufficient to supply considerable moisture by direct surface application but the underlying rock structure is such that it is also an important factor in supplying moisture to the detrital masses.

UNDERGROUND WATER A FACTOR IN CAUSING SLIDES

Reference has been made to the massive, impervious character of the shales, and to the vertical joints existing in the sandstones. (See Fig. 6.) These conditions are characteristic of the two materials in this region. During periods of folding the shales, being somewhat flexible, have largely retained their massive character and mass continuity except in cases of violent disturbance. The sandstones being less flexible have been jointed. The result is that underground, permeating waters are able only here and there to penetrate the shale beds whereas they can flow with considerable ease along joint planes in the sandstone. The shale beds are not uniformly impervious to water however. Some of them are so interbedded with thin layers of sandstone and very silty clay that water can work through them vertically to some extent and to a considerable extent laterally. They are also slightly jointed, though very much less so than the sandstones. Occassionally they have been so broken and tilted by folding as to become somewhat pervious.

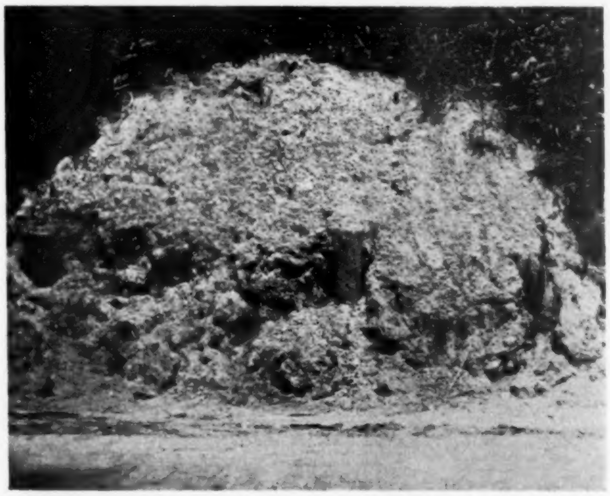

FIG. 10.—DETRITAL SLIDE MOVING THROUGH PILES AND SHOWING FLOW CHARACTERISTICS VERY PLAINLY. THIS SLIDE OCCURRED IN OHIO WHERE THE DETRITUS CONTAINS MORE CLAY AND LESS SANDSTONE THAN IN WEST VIRGINIA

A condition is often found where water penetrates the mass of a high, broad ridge and finds its way freely through sandstone formations and passes along the upper surface of shale beds. It penetrates the shale beds to some extent through fracture planes but generally only in small quantities. If there are a number of alternating beds of sandstone and shale, only a small amount of water will reach the interior of the lower bed.

In many cases some surface water does penetrate great thicknesses of these alternating shales and sandstones but seepage of water is greatest along the upper surface of the shale beds. Water will naturally escape most readily where there is a slope to such a surface. Therefore, seepage will be greatest on the hillsides toward which the structural slope is directed. This means that water will saturate the superficial detritus on such hillsides more readily than on the opposite sides where the strata rise to the point of reaching the surface. It is believed that this is true even when the dip involved is very slight. This does not mean that slides will not occur on both sides of a ridge across which the strata may dip, but it does mean that they will be more frequent and more extensive on the down-dip side.

The great geosynclinal fold, which has been described, causes a general dip of the strata occurring in West Virginia in a direction a little north of west, and, in eastern Ohio, a corresponding dip averaging a little south of east. Minor folds cause local variations of these dips, some of them of considerable magnitude. The dip is sometimes steep but generally it is gentle and one can travel widely in many parts of the area and not notice that there is any dip whatever.

SIZE AND RATE OF MOVEMENT VARIES

Summarizing the foregoing paragraphs, it can be said that slides of detrital masses are brought about by the lubricating qualities of the clay and rounded sand content. The degree of instability depends upon the water content and conditions exist quite generally where this is supplied by underground seepage water, as well as surface water. The slope of the hillside upon which a given mass rests and the conditions of support surrounding it are of course factors in determining the point at which a mass will begin to move. The various illustrations show that the topography is characteristically more or less steep but that cases have been found where a sufficient degree of fluidity has been reached to cause slides on gentle slopes.

FIG. 11.—ANOTHER VIEW SHOWING THE FLUID NATURE OF THE OHIO DETRITUS

A detrital mass may be practically continuous for 300 to 600 feet or more upward, but the slope may be intersected by broad benches of sandstone which until completely overriden tend to protect detritus below from the influence of upper slides, and to limit the

Fig. 12.—Views of the Top, Middle, and Bottom of a Landslide near Huntington, W. Va., Arranged in the Order Mentioned. Note the Beginning of a Break and the Old Slide in the Top Picture, the Fluid Character of Material in the Center Picture and the Upheaval of Material at the Bottom Due to Impact of the Slide

volume of a given slide. Vertical sections of detritus where thickness may be observed are rare, but as a result of many observations of the upper and lower portions of slides and cuts made by steam shovels in removing their débris from highways it appears that the average thickness is not more than 6 or 8 feet. Often over wide areas it is less. The maximum thickness appears to be about 12 feet except on gentle slopes where it may be somewhat thicker and in the lower extremities of old slide masses.

A great majority of individual slides involve a lateral extent varying from 150 to 300 feet; some are more extensive, others less so. Occasionally a long reach of detritus on the verge of instability as a whole may become involved in a local slide and within a few days from the first movement a mass up to a half-mile in length, measured along a road, may be in motion. Most of the natural slides studied measured in length up the slope 150 to 300 feet and in width when considered as individual slides from 200 to 400 feet. A few were found which were 1,000 feet or more broad. Such slides often have no break at the top but thin out there and thicken downward in successive waves which terminate in broad, gently curving lobes.

These slides seldom move more than 50 to 100 feet before a period of stability occurs, which may be merely days or may last months or years. Attention has been called to the fact that individual slides have been seen extending up the slope for a distance of 300 feet. In examining recent slides that have impinged on highways practically continuous slide material has been found for a distance of 600 feet or more up the hill. In such cases, however, the upper portions consist of older slides. Natural slides tend to begin near the top of hills or ridges and are later brought about successively below. The age of many of the older upper slides may be approximately determined in forested areas by the position and relative ages of trees. In one case an examination of old slides 400 feet vertically above a recent slide onto a highway disclosed growing on the rough, pitted slide-mass, one set of trees tilted in various directions and appearing to be from 100 to 125 years of age, while a younger growth all practically erect were approximately 60 years of age. The slide, therefore, occurred somewhere between 60 and 125 years ago but probably not much more than 60 years ago.

The slide movement is sometimes sudden and completed within a few minutes or hours. More often it is leisurely and a matter of days or weeks. Sometimes it consists of a series of short advances repeated at intervals throughout a period of years. Slides from the high, steep bluffs of the Ohio River sometimes drop like avalanches. Although a few of these involve thousands of yards the quantity of material in them is usually small. On high and excessively steep slopes detrital matter can not accumulate in great quantity because slides are too frequent and direct erosion constantly removes the finer material. Near the base of these bluffs there is frequently a wide bench or an area of gentle slope which permits accumulation of detritus there. In such cases when water saturation becomes sufficient large slides move upon the river road.

Such a mass accumulated on the road going up the Ohio River a few miles north of Huntington, W. Va. Old rough, pitted slides are present from 100 to 200 feet up the slope. Two years ago the bottom of this mass which had been cut through when the road was graded moved against and upon the pavement. The road surface was broken and heaved for a distance of 200 or 300 feet, and several thousand yards of débris suddenly covered the road. Temporary stability was then attained, followed by renewals of the forward movement at varying speeds, but most of which were low.

This slide was inspected on the morning after a mass of detritus 12 feet in thickness had been cleaned from the road by a steam shovel. A thin wedge of detrital clay projecting across the ditch from the base of the landslide mass was drying out and had been lifted clear of the ditch. The position of its upper edge was marked on the margin of the pavement. Five hours later it was found that this edge had advanced over the pavement a distance of 2½ inches. Meanwhile the sun had been shining on this thin edge

Fig. 13.—Fissures and Pockets are Typical of Detrital Slides. They Catch Surface Water and are Often Factors in Keeping the Slide Moving

drying and shrinking it. Probably it had shrunk at least an inch laterally in the interval between observations so that the rate of movement of the landslide, at that particular time, was approximately 3½ inches in five hours.

FLOW MOVEMENT OF MANY SLIDES OBVIOUS

There is a widespread opinion among engineers who have to deal with these slides that their movement is one of mass along a sloping glide-plane. They sometimes resort to drilling and blasting for the purpose of breaking up and roughening the surface underlying the slide débris as a mean of control. Observation of hundreds of slides of this type is convincing that movement is usually throughout the mass and not a movement of it as a more or less solid whole, and that such measures are seldom effective. This method of control will be discussed in more detail in a following paper.

The flow character of many slides is plainly obvious especially in Ohio, and occasionally in West Virginia. This type of movement is well illustrated in Figures 10 and 11. These slides consist of much clay and more or less highly rounded, small particles of sand and silt.

Fig. 14.—Natural Landslides Modifying Topography. The Benches are Due to Hard Sandstone Strata

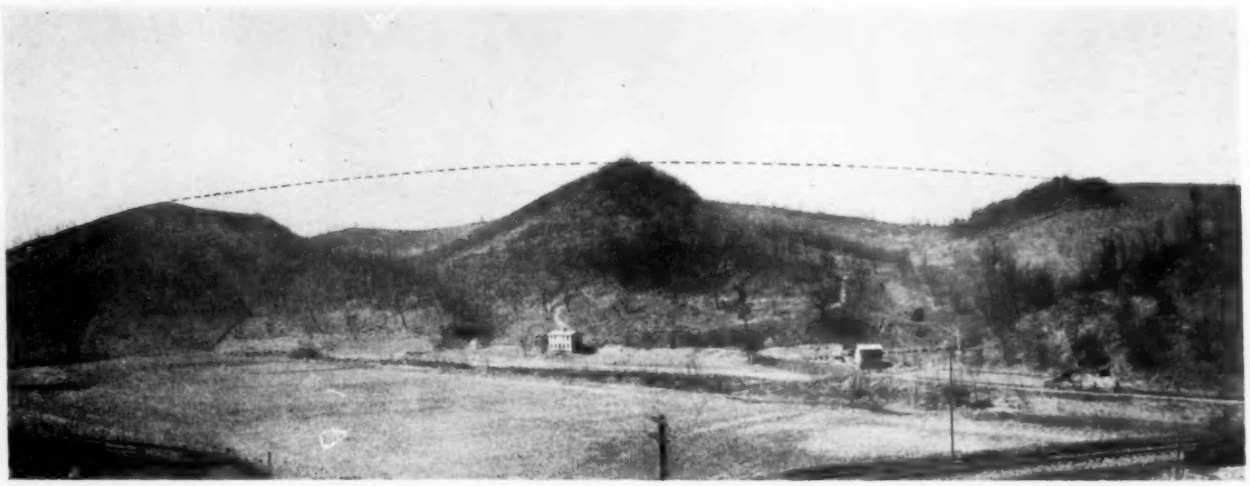

Fig. 15.—Landslides Have Been an Important Factor in the Development of Topography in West Virginia. Dotted Line Shows Old Sky Line

The slide illustrated in Figure 10 is not satisfactorily held back by the row of piling placed for control because when wet the material becomes so fluid that it flows between piles. The mud-flow character of the slide illustrated in Figure 11 is obvious. The hill slope is probably not a factor in the movement of this mass which, although but 10 or 12 feet in thickness, can not support its own weight when saturated with water. In these cases the mass movement is better described as a slump rather than a slide.

The position of trees on recent slides throws light on the nature of the movement. The inclination of trees naturally depends upon the relative motion of the surface as compared with the material immediately beneath the surface. In the center of Figure 12, A, there may be seen a time-rounded mass of an ancient slide. Immediately in front of this is a tree of considerable age which had been tilted backward and subsequently developed for its upper part a vertical position. The recent slide in the foreground played no part in the position of this tree. A definite flow of semifluid material is plainly shown in Figure 12 which shows views of the top, slope, and bottom of a single slide.

Fissures often 8 or 10 feet deep and in parallel rows at right angles to the direction of movement are common phenomena in slides where fluidity of the mass is not high. These fissures are gathering places for surface water and so tend to keep the mass moving. (Figs. 12 and 13.) It often happens that old detritus which is well compacted and sodded on the surface is squeezed and rolled up to a height of 7 or 8 feet by the impact of a slide from above (fig. 12, C) or added weight artificially or naturally imposed upon it.

TOPOGRAPHY DEVELOPED BY DETRITAL SLIDES

In going over this region the geologist is surprised at the major influence detrital slides have had on the formation of topography. Erosion gradually lowers the stream beds, but aside from this its action is confined almost solely to removing the products of landslides. Gulleys and ravines on hillsides are rare and are usually located upon a course prepared by landslides. The

whole process of the continuing development of topographic form, or reducing continuous ridges to short ones, or to isolated hills, is easily observed and strikingly demonstrated.

The development of topographic forms through the agency of landslides is illustrated by Figures 7, 14, and 15. In Figure 7 a natural landslide is shown, but it is foreshortened and the hill flattened as a result of photographic limitations. This slide starts over 300 feet up the slope of the hill and about 150 feet vertically above its toe. At its head lies a jointed bed of sandstone. It may be considered as the beginning of a broad concave cut in the hill which will ultimately reach and involve its crest. Note its glacierlike form, the evident flow of its material, the sharp break at its top, and the piled-up, thickened lower end.

Figure 14 shows a deforested ridge with characteristic benches which are in part if not wholly due to the presence of relatively hard sandstone strata. On the left end of the main ridge two natural slides appear, the upper one being the more recent. Evidence of other slides may be seen at various points toward the right at high elevations. The lower mass of this

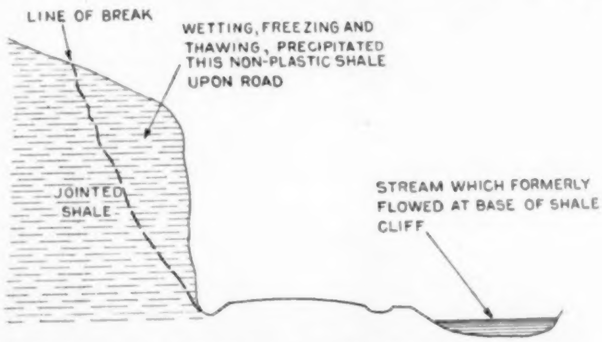

Fig. 16.—As a Result of Frost Action in an Otherwise Stable Shale Stratum Thousands of Tons of Material Fell upon the Highway

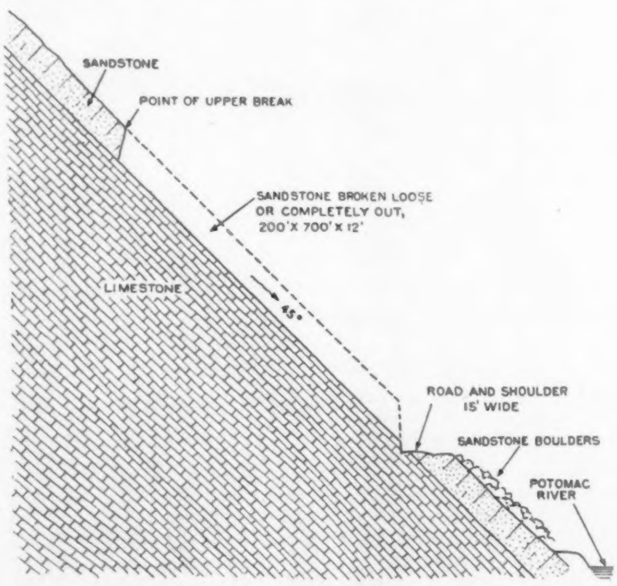

Fig. 17.—Diagram Showing How Bed of Sandstone 12 to 15 Feet Thick Broke Out and Slid on a 45° Slope as a Result of Making a Cut as Shown

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Fig. 18.—Views Looking Up and Across a 45° Slope Where a Slide of Stratified Rock Occurred as a Result of a Highway Cut

ridge just above the flood plain of the stream in the foreground consists wholly of landslide detritus. A few minor erosion channels have developed in this mass. Material at the toe of this slide has been carried away in times of stream flood, exposing steep sections of detritus not yet covered by vegetation.

A panoramic view is shown in Figure 15, which strikingly illustrates the progressive development of broad concave recessions in Pennsylvanian formations as a result of consecutive landslides over a long period of time, and the consequent development of a unique topography. It is easy to visualize the original skyline of the ridge extending clear across this view. On the left-hand side the ridge has been completely broken through and on the right a great cirque has developed which would already have completely penetrated the ridge had it been narrow at this point.

Water erosion has of course aided this topographic development and has necessarily preceded some of the later lateral landslides. As the original landslide was followed by others so that marked recession of form into the ridge was developed, a drainage area followed. This aided subsequent face-slides and was followed by a series of lateral slides. This sequence accompanied by the removal of material by streams has required only the element of time for so extensive a destruction of the ridge.

Just beyond the building nearest the camera there is a small and very recent slide. A little higher up, outlined in its lower half circumference by a road on one side and path on the other, may be seen the area of a considerable and somewhat older slide. Trees are growing on the site of this slide, which must be from 18 to 25 years old. On the left of the illustration a comparatively recent and extensive slide of a lateral nature is in evidence on the right-hand slope of the hill, once part of the continuous ridge.

SLOPE ADJUSTMENT OF SUPERFICIAL MATERIAL A COMMON TYPE OF SLIDE

Slides of material as a matter of slope adjustment are found over a wide area in western West Virginia, and, particularly among the high hills of both States along the Ohio River, where they often occur in considerable volume. This type of slide is confined largely to the Pennsylvanian formations and consists of a steady dribble of rock fragments and shale. The amount of fall is greatly increased in wet seasons and during alternate freezing and thawing spells. It is not often that the quantity of material at any one spot is particularly large but the accumulation on a stretch of road a few miles long is often several thousand tons. (Figs. 2 and 5.) Most of the material is small and easily handled, but the writer has seen a bowlder of massive sandstone weighing many tons bound down a steep slope and, striking the edge of a concrete pavement, dislocate it several inches and split it down the middle for 200 feet or more. No extended discussion as to the underlying causes of this type of slide is needed as it is obvious that they are the same forces and conditions which cause the formation of detrital masses.

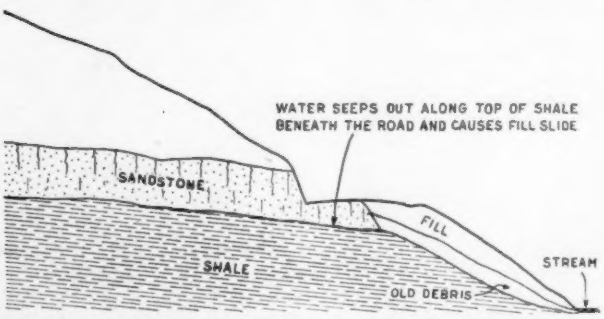

FIG. 19.—ROAD LOCATED SO THAT A SLIDE OF FILL MATERIAL IS ALMOST CERTAIN TO OCCUR. WATER PASSES THROUGH JOINTS IN THE SANDSTONE AND ALONG TOP OF SHALE AND ENTERS FILL BENEATH PAVEMENT

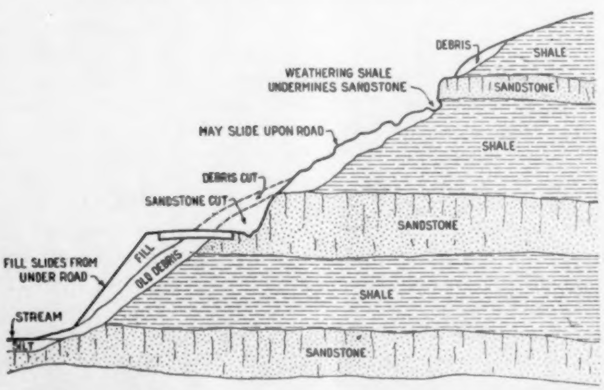

FIG. 20.—CONDITIONS HERE ARE MUCH THE SAME AS IN FIGURE 19 EXCEPT THE ROAD IS PARTLY LOCATED ON SOLID MATERIAL

FIG. 21.—TYPICAL FILL SLIDES. IN THE LOWER PICTURE A NATURAL SLIDE IS TO BE SEEN IN THE FIELD BELOW THE FILL SLIDE

FIG. 22.—A FILL SLIDE THAT HAS UNDERMINED A CONCRETE ROAD. OFTEN LARGE SECTIONS OF THE ROAD BREAK OUT AND ARE CARRIED AWAY

SLOPE ADJUSTMENT OF JOINTED MATERIAL CAUSES FEW SLIDES

Slides which are the result of comparatively small-scale adjustments of jointed material where a vertical face results from an artificial cut are found in a few localities in West Virginia. Those observed by the writer were in the eastern part of Mineral County. The most interesting one occurred where, in order to avoid crossing and recrossing a stream which had undercut a massive shale formation until it stood with a vertical face, the stream course had been deflected, a fill made, and a highway constructed at the foot of the shale cliff. The shale mass here, although not a plastic variety, broke off at the top, probably as the

result of freezing of water in joint fractures, and dumped several thousand cubic yards of material on the road. The slope adjustment resulting from this fall is probably sufficient to provide stability of the shale mass above the road for the immediate future. (Fig. 16.)

SLIDES OF ROCK STRATA RARE BUT CAUSE GREAT DAMAGE

The fourth class of slide which might be described as structural slides occurs when stream erosion or an

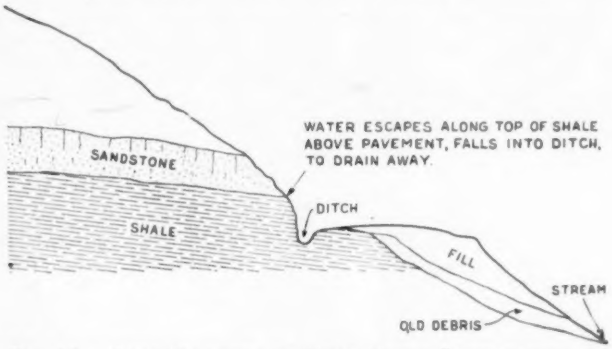

FIG. 23.—ROAD LOCATED SO THAT DITCH INTERCEPTS ALL SEEPAGE WATER UNLESS THE SHALE IS PERMEABLE WHICH IS OF RARE OCCURRENCE. FILL SLIDES SHOULD NOT OCCUR UNDER THESE CONDITIONS

artificial cut removes support from dipping strata, or from rock with dipping cleavage planes. The type is rare in the West Virginia and Ohio region. The best example is found in West Virginia, on the side of a high ridge which overlooks the Potomac River about 1 mile south of Cumberland, Md. At this place beds of massive sandstone lie upon limestone strata, as illustrated in Figure 17, and are probably separated from it by a thin seam of sandy clay. These formations dip toward

FIG. 24.—UPHEAVAL OF OLD DETRITUS CAUSED BY WEIGHT OF FILL. NEW CRACKS CAN BE SEEN AT BACK OF MAN. THE STABILITY OF THE ROAD UNDER SUCH CONDITIONS IS EXTREMELY UNCERTAIN

the Potomac River at an angle of 45°. A roadway was excavated from solid rock along the side of this ridge. Before the road was completed a large rock slide occurred. Breaks opened at two points not far apart. One of these, several feet in width, extended a long distance diagonally up the hillside, but very little of the sandstone slid far enough to do much damage. The second break extended for a distance of about 700 feet measured along the road, and was about 300 feet above it at its farthest point. It resulted in the precipitation of an enormous mass of sandstone upon the road and across it. Figure 18 shows two views of this slide.

A slide occurred in Cumberland, in similar formations with like geological structure. This slide was also due to a highway cut and about 5,000 cubic yards of rock was precipitated upon the highway. The disastrous Sand Patch tunnel slide on the Baltimore & Ohio Railroad was of this type.

FILL SLIDES MOST SERIOUS PROBLEM

Probably more than 50 per cent of the damage to roads and the most serious problems in connection with them in these States are caused by fill slides, that is, the subsidence of fill material from under part or all of the road pavement. Fills made of detrital material have the same tendency toward movement as the natural detrital masses and it is possible that this tendency is increased somewhat by being loosened, worked, and placed in the fill with a lesser degree of compaction.

Through fills seldom give trouble, but under exceptional conditions slips occur in them or they "go out" altogether. Sidehill fills go out sometimes as a result of under-pavement seepage, sometimes as a result of defective culverts, and sometimes because of saturation from prolonged rains. Figures 19 and 20 diagrammatically illustrate ways in which under-pavement seepage

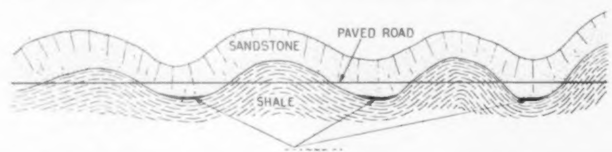

FIG. 25.—SECTION THROUGH FOLDED STRATA OF SANDSTONE AND SHALE WITH SHARPNESS OF FOLDS EXAGGERATED. HORIZONTAL LINE SHOWS POSITION OF HIGHWAY. IN FORMATIONS OF THIS KIND SLIDES HAVE OCCURRED WHERE SEEPAGE ALONG THE UPPER SURFACE OF THE SHALE IS NOT INTERCEPTED BY THE ROAD DITCH

may cause fill slides, and Figures 21 and 22 illustrate slides due to this condition. In these cases the natural seepage channels along the upper surfaces of the shale beds bring about a sufficient degree of fill saturation to cause slides. In the lower illustration of Figure 21 the hill in the background is low, yet it supplied sufficient underground water to cause this fill slide and many natural slides in the field below. Figure 23 shows a condition where seepage water is intercepted by the road ditch and the fill rests on impervious shale. Fill slides should not occur under these conditions.

Figure 24 illustrates a case where the weight of the fill has started a movement of material below and which will soon involve a movement of the fill itself.

A particularly interesting case showing the relation between rock strata and slides was encountered in Mason County, W. Va., and is illustrated in Figure 25. The strata are gently folded in low anticlines and shallow synclines and a road has been located in sidehill cut in such manner as to bring the impervious shale and the jointed sandstone overlying it alternately above and below the pavement. Theory indicates that in this case seepage water will alternately flow into the highway ditch and into the road fill depending on the position of the undulating surface of impervious shale. Field observations demonstrated this theory to be correct. A series of fill slides was found wherever the shale surface dipped below the ditch and a condition of stability existed where it was above.

(Continued on page 35)

STANDARD SIZES OF CRUSHED STONE[1]

Reported by F. H. JACKSON, Engineer of Tests, Bureau of Public Roads

PRACTICALLY every one having to do with either the production or the use of crushed stone will concede at least the theoretical advantages which may be derived from the standardization of sizes. The wide divergence of existing standards of construction, however, coupled with a natural reluctance on the part of engineers to change their practice simply to comply with a national standard, has made progress in this field very slow. The unsystematic development of the various types of bituminous roads has resulted in a demand for a large number of sizes of stone for a comparatively small number of distinct types of construction, the variations often being of academic rather than practical significance.

LARGE NUMBER OF SIZES OF CRUSHED STONE NOT NEEDED

We may classify these variations in requirements in two groups, (1) those due to distinct differences in engineering practice for a given type of construction, and (2) those very small differences in requirements which are in reality meaningless, but which frequently cause considerable trouble. As an illustration of the first class, a survey of 27 current State specifications for penetration bituminous macadam reveals that there are now specified as many as 10 different sizes of stone for use in the penetration course alone, varying all the way from a 1 to 2 inch size to a 2½ to 3½ inch size. As an illustration of the second class, the requirements for size of chips for bituminous macadam in current specifications show an inexcusable number of slight variations in size, such as $\frac{3}{16}$ to $\frac{5}{16}$ inch, ¼ to ½ inch, $\frac{5}{16}$ to ½ inch, and other sizes.

Making every allowance for variations in size necessitated by difference in quality, it is yet obvious that the multiplicity of requirements in force is not only unnecessary and confusing but also works a hardship on the producer, increases the cost of production, and so tends ultimately to increase prices. On the other hand, it must be remembered that it is the engineer in charge of construction and not the producer of the material who is responsible for the quality of the work and he can not be expected to abandon a size with which he has perhaps had many years' satisfactory experience unless he is convinced that the standard size will prove just as satisfactory. And herein lies the greatest difficulty. It is with the engineers and not the producers. Experience with producers in general shows that they are willing to supply what the engineers want, provided the latter will only agree as to just what they do want.

The road materials committee of the American Society for Testing Materials, through its sectional committee on standard sizes of broken stone, broken slag, and gravel, has considered this problem for a number of years and has prepared tentative specifications for commercial sizes of broken stone. These tentative specifications were prepared after an exhaustive study of existing specifications with a view to the selection of the minimum number of primary sizes of crushed stone which would supply the engineers' needs and at the same time eliminate the many small variations in requirements which had no justification other than that they represented the ideas of individual engineers or groups of engineers. This was no easy task because it involved not only the elimination of many sizes for which the committee felt standard sizes could be substituted, but also because it necessitated a careful study of the various factors which influence the efficiency of plant-screening operations in order that the size limits and tolerances specified might be practical from the standpoint of economical production. The problem required a careful balancing of these practical limitations against theoretical requirements.

SURVEY INDICATES FACTORS AFFECTING SCREENING

Before proceeding to a discussion of the proposed standards, it may be of interest to review briefly the results secured from a rather extensive survey of crushed stone plants made by the Bureau of Public Roads several years ago. The survey included over 100 representative commercial plants situated in the New England, Middle Atlantic, and Ohio Valley States. The information secured, while bearing particularly on the screening operation, included data relative to crushers, their number, type and size, speed and arrangement of conveyers, etc. The screen data included the number, type, and arrangement of screens; the nominal as well as actual size of perforations; the length, diameter, pitch, and speed of revolving screens, with the number and length of each section; arrangement of jackets, etc. A record was made of each commercial size produced by the plant with the screen installation as indicated at the time of inspection. This record included the nominal size limits for each product, the name and number under which it was sold, and the specifications it was supposed to meet. Finally, a representative sample of each size was secured from a stock ready for delivery and a screen analysis was made with laboratory screens having circular openings.

From these data it was possible to determine the efficiency of each screening operation at the time of inspection in so far as it was affected by the screens themselves. Other factors which affect screening efficiency, such as fluctuations of the feeding rate and moisture on the stone, were noted and their effect on the particular material selected for sampling determined as nearly as possible. It may be of interest to summarize briefly the conclusions which it was possible to draw from this survey, and they may be stated as follows:

1. The length of a revolving screen influences the grading of the screened product to a marked degree.
2. Within the relatively narrow limits usually found in plant installations pitch and speed of revolving screens apparently have no material influence on grading, probably on account of other predominating factors, such as fluctuation in the rate of feed of stone to the screen, which it is impossible to control in a practical way.
3. The effect of oversize holes due to wear of the screen is practically negligible in view of the relatively large amount of stone held on a revolving screen which theoretically should have passed through it.
4. Small amounts of oversize stone sometimes found in products screened through holes of certain nominal diameter usually are due to faulty bin or chute construction, lack of repair, or other deficiencies in the storing or handling of the material.

[1] Paper read before the tenth annual meeting of the National Crushed Stone Association, Detroit, Mich., Jan. 19, 1927.

5. The grading of the screened product can not be controlled with any degree of certainty by simply specifying the size of openings in the revolving screens over which and through which it shall pass.

6. It is neither practical nor necessary to specify that all material retained on and passing revolving screens of certain sizes shall lie between laboratory screens of the same size.

7. Laboratory screens may be used to control the grading of the plant product if a reasonable tolerance is allowed, that is, one wide enough to cover the recognized inefficiency of the revolving screen and yet close enough to insure sufficiently well-graded materials.

8. Inspection of the results of hundreds of screen analyses indicates that as much as 5 per cent of material should be allowed larger than the size of perforations in the revolving screen through which the product is supposed to pass, and as much as 15 per cent generally should be allowed smaller than the size of the perforations in the revolving screen upon which it is supposed to be retained.

PLANT LIMITATIONS RECOGNIZED

The last conclusion applies, of course, only to products sized with revolving screens and presupposes an adequately designed plant and efficient operation. It applies to the so-called primary sizes only, that is, those sizes the upper and lower limits of which are close together, as ¾ to 1¼ inches. With combined sizes, such as are used as concrete aggregate, ¼ to 2½ inches for example, the tolerance on the lower limit may and should be materially reduced.

With regard to the method of specifying the sizes desired, there are still many engineers who believe that it is necessary to tell the producer just what plant screens to install in order to obtain the sizes they desire. The operator of the average commercial plant is in a much better position to decide on the particular screen installation he needs than the engineer, who should specify only the size or sizes desired in such a manner as to admit of but one interpretation; that is, by reference to laboratory screens. It then becomes the operator's duty to study his installation so as to produce the material in the most efficient manner. Viewed from this angle, the object of the 5 and 15 per cent tolerances just mentioned is simply to recognize the practical limitations beyond which it is impossible to carry efficient operation without greatly increasing the cost.

The facts which were brought out by the survey were of course available for the use of the committee on standard sizes of the American Society for Testing Materials, and form the principal basis of the committee's recommendations as regards tolerances in their proposed specification.

FIVE STANDARD SIZES OF CRUSHED STONE PROPOSED

The committee was, at the outset, confronted with the necessity of reducing the number of primary sizes to a minimum consistent with sound engineering practice. Moreover, it was recognized that the limits of the various primary sizes should not overlap, and when taken together should represent the entire output of a plant. It was also felt that if possible the number of primary separations should be limited to five, due to the greatly increased cost of producing more than five primary sizes in one plant at one time. It is interesting to note in this connection that many large producers replying to a recent invitation from the National Crushed Stone Association to criticize the proposed standard, stated that from the standpoint of economic production, the number of primary sizes should be limited to five.

The committee also considered very carefully the question of nomenclature. What would be the simplest and most easily understood method of designating sizes? At present there are many systems in use, to the utter confusion of everyone. We have No. 3 stone; we have 1-inch stone, and we have pea stone, to mention three methods of designating sizes and these designations do not always mean the same thing in different localities. No. 1 stone in one State may be described as No. 3 stone in an adjoining State. What does the purchaser mean when he asks for a car of 1-inch stone? Does he mean a maximum size of 1 inch or an average size of 1 inch and if so what are his upper and lower limiting sizes?

The committee after carefully considering the various systems in current use decided that the simplest as well as most definite method of designation would be to specify both the upper and lower limiting sizes, as, for instance, ¼ to ¾ inch size, ¾ to 1¼ inch size, etc., which together with a standardized schedule of tolerances and intermediate requirements would give a clear understandable designation, provided a method could be agreed upon for measuring size. There has been a considerable difference of opinion on this point and it has been difficult to bring about agreement between those who favor the square mesh on account of its application in the design of concrete by the fineness modulus method, and those who favor the round hole because it has been used for many years for measuring the size of crushed stone for bituminous road work, and in general is considered a more accurate measure of size than the square opening. However, the committee on road materials of the American Society for Testing Materials, which contains representatives of both sides, last year went on record as favoring the round aperture, and with this precedent the sectional committee on standard sizes decided to submit its tentative schedule of sizes with this method of measuring as the basis. In other words, when we say ¼ to ¾ inch size, we mean that portion of the product of the crusher at least 85 per cent of which will be retained upon a laboratory screen having circular openings ¼ inch in diameter and not more than 5 per cent of which will be retained upon a laboratory screen with circular openings ¾ inch in diameter.

On the basis of five primary sizes as the maximum limit and after careful study of existing specifications, the committee proposed the following divisions of the crusher run from 0 to 3½ inches:

0 to ¼ inch.
¼ to ¾ inch.
¾ to 1¼ inches.
1¼ to 2½ inches.
2½ to 3½ inches.

These separations are to be on the basis of laboratory screens with round openings. Assuming that, in general, stone will crush in such a way that the percentage of the total crusher run passing any particular size screen will be in proportion to the size of the opening—that is, conforming to a straight-line grading—then the relative percentages of the total crusher run obtained in each of the five primary sizes would be about as follows:

0 to ¼ inch—10 per cent.
¼ to ¾ inch—15 per cent.
¾ to 1¼ inches—15 per cent.
1¼ to 2½ inches—35 per cent.
2½ to 3½ inches—25 per cent.

The relative percentages of the various sizes will, of course, vary in individual cases with the kind of stone, type of crushers, and amount of recrushing. For

general conditions, however, and assuming that stone above 3½ inches is rejected and recrushed, the above may be considered an indication of average results. A recent report,[2] based on elaborate plant tests, substantially confirms the above figures.

PROPOSED SIZES MEET ALL ORDINARY REQUIREMENTS

The above system of sizes was considered with a view to ascertaining to what extent each size would be available to the engineer and how the sizes could be combined, remembering that for each primary size a tolerance of 15 per cent is allowed on the lower limit and 5 per cent on the upper limit. The problem of establishing standard size limits so as to care for the entire output of all plants with a minimum of waste at all times is, of course, a hopeless one. There are uncontrollable fluctuations in demand which may cause a certain size to be in great demand one month and a drug on the market the next. There may be a difference in the demand for stone of different kinds. The supply of limestone in certain sizes required for road work or as concrete aggregate may be greatly affected by the demand for flux stone or agricultural limestone, while trap rock would not be affected by the latter demands. It is obviously impossible to carry standardization to the point where a uniform standard of plant practice is possible. Every plant and every producing district has its own peculiar problems and the best that standardization can do is to provide a common measure for the use of the engineer in making known his needs to the producer so that the latter will know exactly what the former wants and the former will know exactly what the latter has to offer.

Considering the uses to which the several suggested sizes may be put, let us take first the ¼ to ¾ inch size. This is commercial ½-inch stone, very largely used in road work as chips in bituminous macadam construction by the penetration method, in certain grades of bituminous concrete, as a surface dressing, and in maintenance work. It was felt that a tolerance of 15 per cent on the lower limit gave a reasonably well sized product, and was liberal enough for economic production. The next size, ¾ to 1¼ inch, is commercial 1-inch stone, with the same tolerance of 15 per cent. It may be used alone as the intermediate course in bituminous macadam, or in combination with the ¼ to ¾ inch size in certain grades of bituminous concrete or as an aggregate in Portland cement concrete, where the maximum size must not exceed 1¼ inches. A combination size made up of the ¼ to ¾ inch size and the ¾ to 1¼ inch size, each of which complies with specifications for that size, may reasonably carry a somewhat lower tolerance than 15 per cent—10 per cent at most and possibly 5 per cent in the case of concrete aggregate where a relatively large percentage of the ¾ to 1¼ inch size should be used in the mixture.

The next size, 1¼ to 2½ inches, is proposed for use in macadam road construction, either penetration or waterbound. Objection has been raised to this size for penetration macadam on the ground that a larger size, say, 2 to 3 inches, would give better results and that the maximum size stone should be limited only by the depth of the course. Reviewing the several State highway department specifications, we find a wide divergence of practice. Out of 27 State specification standards, there are 3 with a maximum size of 2 inches, 12 with a maximum of 2½ inches, 7 with a maximum of 2¾ inches, 5 with a maximum of 3 inches, and 1 with a maximum of 3½ inches, the latter to be used only in courses exceeding 3 inches in depth. This indicates the difficulties in the way of pleasing everybody. It may be suggested that a compromise could be made by raising the upper limit to 3 inches without realizing that to do so would throw the entire specification out of balance by eliminating the 2½-inch separation which is insisted upon by the users of concrete aggregates. At the present time the committee is inclined to adhere to the present limit of 2½ inches for bituminous macadam where the course is less than 3 inches in depth and to suggest the 2½ to 3½ inch size where the course is greater than 3 inches in depth.

STANDARD SIZES SUITABLE FOR CONCRETE AGGREGATE

We now have three primary sizes which together represent the run of the crusher from ¼ inch to 2½ inches. When properly combined, these three sizes may be used to produce an ideally graded aggregate for concrete for pavements where the maximum size is 2½ inches. Just what constitutes an ideal grading for coarse aggregate for pavements makes an interesting problem for discussion, both from an economic and an engineering standpoint. Recent investigations made by the Bureau of Public Roads in cooperation with the New Jersey State Highway Commission indicate that the yield of concrete from given volumes of the constituent materials is greatly influenced by the grading of the coarse aggregate. As an illustration, it was found that in the case of a 1:1¾:3½ mix, using crushed trap rock as coarse aggregate, a stone graded uniformly from 2½ inches to ¼ inch in size required 6.18 bags of cement per cubic yard of finished concrete as compared to 6.72 bags required when the material under 1 inch in size was omitted—a saving in cement of about one-half bag per cubic yard. It is true that a considerably greater weight of stone was required in the case of the well-graded aggregate than in the case of the poorly graded material, so that from a strictly economic point of view the gain in cement would be somewhat offset by the additional stone required. The economic aspects of concrete proportioning have not received the attention that they should.

If we assume for the moment that the ideal grading curve for stone between ¼ inch and 2½ inches in size is approximately a straight line, which according to Taylor and Thompson is the condition of maximum density, it would be necessary to mix the three commercial sizes in approximately the following proportions:

1¼ to 2½ inch size—60 per cent.
¾ to 1¼ inch size—25 per cent.
¼ to ¾ inch size—15 per cent.

This is very nearly the ratio in which these sizes are produced in the normal crushing process, and would therefore be the most economical way for the producer to ship, provided he did not have a heavy demand for ¼ to ¾ inch size, which is often the case. However, the point to be emphasized here is that in concrete work it is highly important to have a uniform grading of coarse aggregate from day to day if satisfactory results are to be obtained. This rule holds irrespective of the method used in designing the mix. As a matter of fact, it is even more important viewed in the light of some of the new theories of concrete design which have been advanced, due principally to the effect of

[2] A Study of the Mechanical Analysis of Crushed Stone, the Crushed Stone Journal, July 1, 1926, published by the National Crushed Stone Association, Washington, D. C.

variations in gradation on the workability of the concrete and consequently on the amount of water which must be used in order to properly place the mix. Variation in the amount of water used in the mix will affect the strength of the concrete, resulting in a nonuniform product. From the viewpoint of the producer it is of great importance to maintain uniformity in the gradation of aggregates for concrete even though the specification may allow a considerable variation in some of the intermediate sizes. Rigid attention to such details will do more to overcome the natural disadvantages of crushed rock as compared to certain other aggregates than will any other one thing and will at the same time insure better concrete.

The remaining size in the crusher-run product is from 2½ to 3½ inches, and would be available for use either as base course in waterbound or as bituminous macadam for courses over 3 inches in depth. In times of heavy demand for the smaller sizes, this size could, of course, be recrushed as desired.

PROBLEM NOT YET ENTIRELY SOLVED

The original tentative standard specifications of the American Society for Testing Materials have been amended once by the insertion of a 0–½-inch size to provide stone for Topeka-type pavement. Many additional changes have been suggested both voluntarily and in response to inquiries sent out by the committee. Among them is a request for a commercial ¾-inch stone, from ½ inch to 1 inch in size, for use in tar macadam. The sponsors for this size claim that the ¾ to 1¼ inch size is too large for intermediate-size stone in bituminous macadam. Here again engineering opinion causes difficulty in the adoption of a rational standard, because it can readily be seen that the ½ to 1 inch size has no place in the system as above outlined.

Strong representation has also been made by certain eastern groups that a ⅝-inch limiting size be substituted for the ¾-inch limit. This size is very largely used in the East now as the lower limiting nominal size for cement concrete aggregate, and there seems some merit to the contention that with the ¼-inch lower limit there is danger of obtaining too high a percentage of small stone which makes a very harsh concrete, difficult to finish properly. The above illustrations are given simply to show that the problem has by no means been solved and will require a great deal more work on the part of intelligent, sympathetic representatives of both the producing and the consuming interests before it is solved.

It should not, however, be assumed that no progress has been made since this matter first came up for discussion. The sizes as proposed have been adopted as tentative by the American Association of State Highway Officials, the Federal Specification Board and the Asphalt Association. It will be seen, therefore, that the specifications have advanced considerably beyond the initial stage. The specifications as adopted by these agencies, however, with the exception of those of the Federal board, are in the nature of typical rather than governing specifications, and are in no sense mandatory.

In conclusion, there seem to be three possible courses which may be followed toward the ultimate solution of this vexing question. We may work for the standardization of the suggested series of sizes; or failing that, suggest other sizes which may be substituted therefor; or failing that, abandon all idea of adopting a national standard, acknowledging that the question of the actual sizes to be used is a problem for each producing district to work out in conjunction with the consumers it serves. In the latter event, the committee of the American Society for Testing Materials would confine its attention to the standardization of methods of designation, standard tolerances, and standard methods of measuring size.

CORRECTION

In the March issue of Public Roads in the article "The trend of highway design" a radical sign was omitted in printing the formula on page 8 for road widening on curves. This formula should have been printed as follows:

$$W = 2(R - \sqrt{R^2 - L^2}) + \frac{35}{\sqrt{R}}$$

In which W = Widening in feet.
R = Radius of curve in feet.
L = Wheel base of vehicle in feet.
(Twenty feet recommended.)

In the January issue, in the discussion of earth pressures on culvert pipes by Dean Anson Marston, the following legend should be substituted for the one printed under Figure 2c on page 227:

Yielding of foundation and shortening of vertical diameter is such that the settlement of the fill material directly over the conduit is greater than in the fill alongside the conduit only above a level somewhat below the top of embankment. Below that level the settlement alongside is equal to or greater than the settlement directly above the conduit.

(Continued from page 31)

The various types of landslides which have been described are found in a large area embracing many hundreds of miles of highway. Past experience has been that they not only require the constant expenditure of large sums of money which might go into the improvement of other roads, but what will be of ever-increasing importance, they are serious obstacles to the flow of highway traffic. If ordinary road construction and slide control methods are followed, a continuation of landslide troubles may be expected indefinitely, especially of those occurring under half-fill roads. As a result of the studies which have been made it is believed that much can be done to improve these conditions. The problem is of sufficient importance to deserve exhaustive detailed study, even though it results only in partially correcting or alleviating troubles resulting from landslides.

MOTOR VEHICLE REGISTRATION AND REVENUE, 1926

Reported by L. A. ABBOT, Associate Statistical Engineer, United States Bureau of Public Roads

During the calendar year 1926 there were over 22,000,000 motor vehicles registered in the United States or more than double the registration of 1921 and four times that of 1917. The year's registration represents an increase of 10.3 per cent or slightly over 2,000,000 more than that of 1925. Of the total number of vehicles registered 19,237,171 were passenger automobiles, taxis, and busses, and 2,764,222 were motor

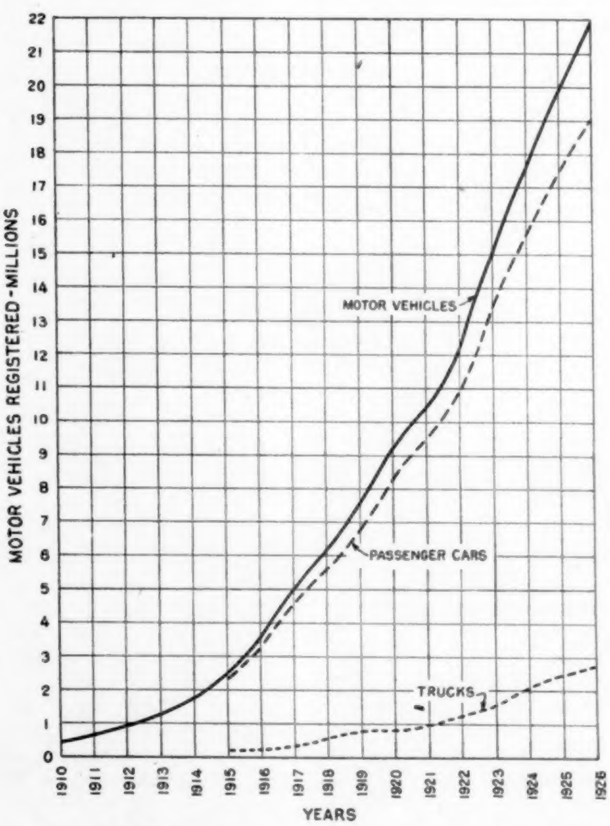

FIG. 1.—MOTOR VEHICLE REGISTRATIONS 1910–1926

trucks and road tractors. Complete details of motor vehicle registration and taxation as collected by the bureau are given in Tables 9 and 10.

Florida, with an increase of 40.2 per cent, excluding nonresident registrations as in other States, showed a greater gain than any other State. Oklahoma, with a gain of 17.8 per cent, and second only to Florida in respect to the percentage of increase, was followed closely by Alabama, Idaho, Louisiana, Mississippi, and Utah, all of which had increases over 15 per cent.

The receipts from registration fees, licenses, and so forth, amounted to $288,282,352 as compared with $260,619,621 in 1925. Of the gross receipts $191,111,302 was available for highway purposes under the supervision of the State highway departments, $51,702,184 was allocated to counties for expenditure on local roads, and $25,274,178 was used for payments on highway bond issues. The remainder was used for payment of collection costs and miscellaneous purposes.

Figure 1 shows graphically the number of motor vehicles registered in the United States from 1910 to the present time. In 1895 four automobiles were produced and the number increased steadily to 1910 when approximately 460,000 motor vehicles were registered. From 1910 the curve rises rapidly upward to 1915 and then even more rapidly to 1923. Since 1923 the curve has declined slightly in steepness but it is still much steeper than at any period prior to 1923. The curve does not show any considerable flattening such as would indicate the near approach to a saturation point in the United States as a whole.

Curves representing the registration of passenger vehicles and trucks separately are also shown. The percentage of trucks to total vehicles in 1926 was 12.5 per cent as compared with 9.4 per cent in 1921. The greatest increase in truck registration was in 1924 when there was an increase of 580,459 or 37.3 per cent over 1923. The 1925 and 1926 increases have been 308,681 and 322,513, respectively, which indicates continued growth of commodity transportation by highway.

Table 1 shows the increase in registration each year since 1921, the accumulated increase since 1921 and these figures expressed as a percentage of the 1921 registration. The last column shows the year 1923 to be the one of largest increase with 27.2 per cent and successively smaller percentages in each of the years following. Figure 2 shows the same facts graphically with 1920 as a base.

TABLE 1.—*Motor vehicles registered each year since 1921, accumulated increase since 1921 and annual increase compared on a percentage basis with the 1921 registration*

Year	Total motor vehicles registered	Increase over previous year	Accumulated increase over 1921	Accumulated increase as a percentage of 1921 registration	Annual increase as a percentage of 1921 registration
				Per cent	*Per cent*
1921	10, 463, 295				
1922	12, 238, 375	1, 775, 080	1, 775, 080	17. 0	17. 0
1923	15, 090, 936	2, 852, 561	4, 627, 641	44. 2	27. 2
1924	17, 593, 677	2, 502, 741	7, 130, 382	68. 1	23. 9
1925	19, 937, 274	2, 343, 597	9, 473, 979	90. 3	22. 2
1926	22, 001, 393	2, 064, 119	11, 538, 098	110. 2	19. 9

TABLE 2.—*Accumulated increases in motor-vehicle registrations since 1921 expressed as a percentage of the 1921 registration by geographic divisions*

Geographic division	1922	1923	1924	1925	1926
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
New England	11. 7	35. 7	62. 0	82. 7	95. 7
Middle Atlantic	22. 5	51. 0	77. 3	99. 2	120. 8
East North Central	18. 0	46. 4	69. 3	89. 0	107. 7
West North Central	11. 2	28. 1	41. 0	57. 2	69. 3
South Atlantic	17. 9	50. 1	82. 5	113. 5	145. 0
East South Central	16. 9	53. 9	85. 7	124. 3	153. 7
West South Central	15. 4	49. 2	78. 7	114. 5	139. 4
Mountain	8. 8	30. 6	48. 2	69. 2	84. 0
Pacific	22. 6	55. 0	83. 7	102. 0	123. 2
United States	17. 0	44. 2	68. 1	90. 3	110. 2

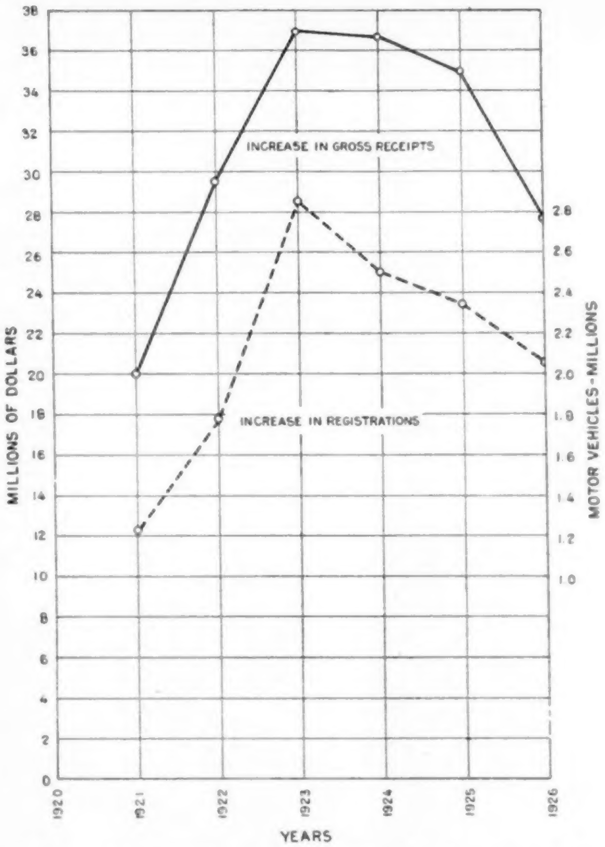

FIG. 2.—ANNUAL INCREASES IN MOTOR VEHICLE REGISTRATIONS AND REGISTRATION REVENUE OVER PRECEDING YEAR

TABLE 3.—*Annual increases in motor-vehicle registrations expressed as a percentage of the 1921 registration by geographic divisions*

Geographic division	1922	1923	1924	1925	1926
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
New England	11.7	24.0	26.3	20.7	13.0
Middle Atlantic	22.5	28.5	26.3	21.9	21.6
East North Central	18.0	28.4	22.9	19.7	18.7
West North Central	11.2	16.9	12.9	16.2	12.1
South Atlantic	17.9	32.2	32.4	31.0	31.5
East South Central	16.9	37.0	31.8	38.6	29.4
West South Central	15.4	33.8	29.5	35.8	24.9
Mountain	8.8	21.8	17.6	21.0	14.8
Pacific	22.6	32.4	28.7	18.3	21.2
United States	17.0	27.2	23.9	22.2	19.9

TABLE 4.—*Comparison of per capita wealth and number of persons per motor vehicle arranged in order of the latter by geographic divisions* [1]

Geographic division	Property wealth per capita, 1922	Motor vehicles per 1,000 of population		Per cent increase in motor vehicles from 1921 to 1926	Persons per motor vehicle	
		1921	1926		1921	1926
Pacific	$3,934	170	326	123	5.9	3.1
West North Central	3,588	147	241	69	6.8	4.1
East North Central	3,063	118	223	108	8.5	4.5
Mountain	3,435	116	187	84	8.6	5.4
West South Central	1,857	80	174	139	12.5	5.7
New England	3,186	94	170	96	10.7	5.9
Middle Atlantic	3,352	78	159	121	12.8	6.3
South Atlantic	2,005	63	141	145	15.8	7.1
East South Central	1,437	44	106	154	22.9	9.4
United States	2,918	97	188	110	10.3	5.3

[1] Bureau of the Census estimate of population for 1921 and 1926 used in compiling table.

TABLE 5.—*New motor vehicles registered* [1]

Year	New production of motor vehicles	Motor vehicles exported	Production remaining in United States	Motor vehicles imported	Net new motor vehicles to be registered
1921	1,724,241	38,430	1,685,811	522	1,686,333
1922	2,254,088	78,234	2,175,854	483	2,176,337
1923	3,673,087	151,894	3,521,193	853	3,522,046
1924	3,763,649	178,732	3,584,917	604	3,585,521
1925	3,768,410	302,931	3,465,479	678	3,466,157
1926	4,621,774	305,256	4,316,518	813	4,317,331

[1] Data from United States Department of Commerce. New production figures are for years ending Sept. 30, as cars manufactured after this date do not ordinarily appear in registration figures until the following year. Import and export figures are for calendar year.

TABLE 6.—*New motor vehicles to be registered, discarded motor vehicles replaced and relation to new production and total registered*

Year	Net new motor vehicles to be registered	Increase in motor vehicle registration	Motor vehicles discarded	Discarded motor vehicles as a percentage of	
				New vehicles registered	Total registered
				Per cent	*Per cent*
1921	1,686,333	1,231,354	454,979	27.0	4.3
1922	2,176,337	1,775,080	401,257	18.4	3.2
1923	3,522,046	2,852,561	669,485	18.7	4.4
1924	3,585,521	2,502,741	1,082,780	30.1	6.1
1925	3,466,157	2,343,597	1,122,560	35.2	5.6
1926	4,317,331	2,064,119	2,253,212	52.2	10.2
Total or average	18,753,725	12,769,452	5,984,273	31.9	....

TABLE 7.—*Motor vehicle revenue 1920–1926*

Year	Gross receipts	Increase over previous year		Revenue compared with that of 1920	Year's increase	Receipts per motor vehicle	
		Amount	Per cent			Average	Percentage of average amount in 1920
				Per cent	*Per cent*		*Per cent*
1920	$102,546,212	....	....	100	....	$11.10	100
1921	122,478,654	$19,932,442	19.4	120	20	11.70	105
1922	152,047,824	29,569,170	24.1	148	28	12.32	111
1923	188,970,992	36,923,168	24.3	184	36	12.52	113
1924	225,630,760	36,659,768	19.4	220	36	12.82	115
1925	260,619,621	34,988,861	15.5	254	34	13.07	118
1926	288,282,352	27,662,731	10.6	281	27	13.10	118

TABLE 8.—*Disposition of motor vehicle gross receipts for the years 1925 and 1926*

Purpose	1925 [1]		1926	
	Amount	Per cent	Amount	Per cent
State highways	$177,666,595	68.1	$191,111,302	66.2
Local roads	46,041,624	17.7	51,702,184	17.9
State road bonds	11,819,689	4.5	19,861,995	6.9
County road bonds	7,304,325	2.8	5,412,163	1.9
Miscellaneous	3,563,087	1.4	3,592,497	1.3
Administration and collection	14,224,301	5.5	16,602,211	5.8
Total	260,619,621	100.0	288,282,352	100.0

[1] Slight revision has been made in the 1925 figures as first published on account of later and more complete information.

TABLE 9.—*Motor vehicle registrations for the year 1926*

State	Registered motor vehicles individually and commercially owned [1]			Other registered vehicles		Tax-exempt official vehicles and motor cycles			Number of licenses or permits (autos)			Total registered motor cars and trucks, 1925	Year's increase in motor vehicle registrations	
	Total registered motor cars and trucks	Passenger automobiles, taxis, and busses	Motor trucks and road tractors	Trailers [2]	Motor cycles	United States cars	State and local cars	Motor cycles	Dealers	Operators	Chauffeurs		Number	Per cent
Alabama	225, 930	197, 983	27, 947	983	401	167			447		1, 813	194, 580	31, 350	16. 1
Arizona	73, 682	63, 294	10, 388		337	176	675		232	86, 221	192	68, 029	5, 653	8. 3
Arkansas	209, 419	179, 480	29, 939	1, 584	279	39	629		527		5, 131	183, 589	25, 830	14. 1
California	1, 600, 475	1, 384, 152	[3] 216, 323	[4] 30, 818	10, 363	1, 217	[5] 20, 248	415	3, 194	112, 170	([6])	1, 440, 541	159, 934	11. 1
Colorado	248, 613	227, 708	20, 905	[7] 86	1, 480	283	([8])		3, 400	21, 967	7, 762	240, 097	8, 516	3. 5
Connecticut	263, 235	222, 283	40, 952	326	3, 108	71	2, 326		5, 231	292, 253		250, 669	12, 566	5. 0
Delaware	44, 834	36, 246	[3] 8, 588	199	342	44			630	45, 067	4, 088	40, 140	4, 694	11. 7
Florida	401, 562	[9] 331, 892	[9] 69, 670	[10] 1, 000	1. 390	75	2, 926	180	3, 295		10, 854	286, 388	115, 174	40. 2
Georgia	277, 468	241, 949	35, 519		841	934			864		3, 197	248, 093	29, 375	12. 3
Idaho	94, 760	86, 339	8, 421	180	483	103	1, 125	26	402		414	81, 506	13, 254	16. 3
Illinois	1, 370, 503	1, 195, 897	174, 606	3, 258	6, 156	979	([11])	([12])	4 703		93, 368	1, 263, 177	107, 326	8. 5
Indiana	772, 326	665, 126	107, 200	5, 697	3, 738	3, 184	3, 593		2, 489		39, 828	725, 410	46, 916	6. 5
Iowa	698, 998	648, 218	50, 780	153	1, 934	44	2, 700	79	2, 291		11, 047	659, 202	39, 796	6. 0
Kansas	491, 276	441, 373	[3] 49, 903	1, 221	1, 330	192	2, 150	50	2, 534			457, 033	34, 243	7. 5
Kentucky	281, 557	252, 632	28, 925	([13])	672	90	1, 444	40	1, 162		9, 299	261, 647	19, 910	7. 6
Louisiana	239, 500	204, 000	35, 500		500	209						207, 000	32, 500	15. 7
Maine	151, 486	124, 158	27, 328	871	1, 124	64	1, 050	71	1, 210	173, 917	6, 327	140, 499	10, 987	7. 8
Maryland	252, 852	240, 743	12, 109	634	4, 039	1, 969			6, 027	37, 938	39, 816	234, 247	18, 605	7. 9
Massachusetts	690, 190	593, 234	96, 956	464	9, 215	556	900		2, 134	763, 951		646, 153	44, 037	6. 8
Michigan	1, 118, 785	969, 686	[3] 149, 099	13, 628	3, 438	371	[14] 5, 875	([12])	2, 133	224, 697	81, 382	989, 010	129, 775	13. 1
Minnesota	630, 285	559, 128	71, 157	2, 666	2, 551	252	306		2, 193			569, 694	60, 591	10. 6
Mississippi	205, 200	184, 133	21, 067	757	92	74	([11])	([12])	5, 468			177, 262	27, 938	16. 3
Missouri	654, 554	587, 856	66, 698	1, 489	2, 005	311	1, 350	5	2, 293	5, 242	24, 933	604, 166	50, 388	8. 3
Montana	103, 958	88, 840	15, 118		192	229	1, 026	11	447		384	94, 656	9, 302	9. 8
Nebraska	366, 773	337, 989	[15] 28, 784		1, 268	226			2, 834			338, 719	28, 054	8. 3
Nevada	24, 014	19, 300	4, 714	60	82	42	379		110			21, 169	2, 845	13. 4
New Hampshire	89, 001	78, 400	10, 601	535	1, 444	22	300		484	66, 600	32, 550	81, 498	7, 503	9. 2
New Jersey	651, 415	531, 702	119, 713	1, 602	7, 235	708	5, 251		2, 460	745, 659		580, 554	70, 861	12. 2
New Mexico	54, 996	53, 173	1, 823	143	200	156	527	5	145			49, 111	5, 885	12. 0
New York	1, 815, 434	1, 508, 314	307, 120	6, 175	18, 303	1, 666	[14] 10, 847		4, 414	1, 568, 540	554, 769	1, 625, 583	189, 851	11. 7
North Carolina	[16] 385, 047	352, 217	32, 830	500	870	429	4, 110		8, 157			340, 287	44, 760	13. 1
North Dakota	157, 822	145, 571	12, 251		305	3	122					144, 972	12, 850	8. 9
Ohio	1, 480, 246	1, 295, 020	185, 226	[17] 9, 150	[17] 12, 130	2, 362	7, 418	278	3, 777		4, 703	1, 346, 400	133, 846	9. 9
Oklahoma	499, 938	449, 955	[18] 49, 983		719	530						424, 345	75, 593	17. 8
Oregon	233, 568	214, 946	18, 622	812	2, 123	141	1, 754	92	604	44, 677	15, 328	216, 553	17, 015	7. 9
Pennsylvania	1, 455, 184	1, 264, 453	190, 731	3, 313	13, 672	1, 383	3, 047	937	28, 167	1, 637, 188		1, 330, 433	124, 751	9. 4
Rhode Island	110, 746	91, 798	18, 948	45	1, 303	56	577	50	278	126, 630		101, 756	8, 990	8. 8
South Carolina	181, 189	163, 551	17, 638	1, 006	270	91	5, 048		519	152		168, 496	12, 693	7. 5
South Dakota	168, 230	153, 840	14, 390		249	85	768		1, 051			168, 028	202	0. 1
Tennessee	279, 639	254, 342	25, 297	([13])	751	132	[14] 2, 066		599			244, 626	35, 013	14. 3
Texas	1, 049, 869	944, 905	104, 964	6, 920	2, 679	2, 505			3, 635		10, 978	975, 083	74, 786	7. 7
Utah	85, 380	72, 880	12, 500	430	576	173	[14] 705					[19] 73, 427	11, 953	16. 3
Vermont	74, 063	68, 524	5, 539	133	606	28			700	66, 154	13, 432	69, 576	4, 487	6. 4
Virginia	322, 614	273, 764	48, 850	437	2, 125	1, 141	[14] 2, 551	471	3, 915		8, 700	282, 650	39, 964	14. 1
Washington	363, 279	310, 386	52, 893	1, 826	2, 740	637	4, 260	153	4, 914	427, 507		328, 442	34, 837	10. 6
West Virginia	227, 836	201, 645	26, 191	329	1, 273	33	2, 007		12, 011	60, 355	27, 000	217, 589	10, 247	4. 7
Wisconsin	662, 282	581, 994	80, 288	([13])	3, 107	92	484	76	2, 785	681, 800		594, 386	67, 896	11. 4
Wyoming	49, 883	44, 358	5, 525		179	209	212		293			47, 711	2, 172	4. 6
District of Columbia	111, 497	97, 794	13, 703		1, 327	837	2, 006	194	1, 906	70, 146		103, 092	8, 405	8. 2
Totals	22, 001, 393	19, 237, 171	2, 764, 222	99, 430	131, 546	[20] 33, 179	102, 762	3, 133	137, 064	7, 258, 831	1. 007, 295	[19] 19, 937, 274	2, 064, 119	10. 3

[1] The first three columns record the regularly registered motor cars and trucks which pay the regular license fees eliminating reregistrations and nonresident owners' cars. The grand total of the first column is subdivided as indicated, passenger cars being shown in second column and freight service trucks and road tractors in the third column. Some States, as noted, classify busses with trucks. Special tables showing the extent and kinds of bus service from non-Government sources can be found in the February, 1927, issue of "Bus Transportation."

[2] Some States include trailers with motor trucks, as noted.

[3] Busses included with trucks.

[4] Excludes 2,232 tax-exempt trailers, of which 1,490 are owned by public-service corporations.

[5] Includes 8,278 cars and trucks of public-service corporations exempt by law.

[6] Included with operators.

[7] Includes road tractors.

[8] Included with registered cars, as all pay regular license.

[9] Nonresident registrations estimated and excluded from figures reported.

[10] Estimated and excluded from motor trucks as reported.

[11] Included with private cars at a special low fee.

[12] Included with private motor cycles.

[13] Not registered.

[14] As reported on July 1, 1926.

[15] Includes only trucks and busses over 3,000 pounds in weight; others classed as passenger cars.

[16] Figures estimated for last six months of calendar year, as registration begins on July 1.

[17] Estimated as trailers and motor cycles reported together.

[18] Excludes 16,274 agricultural tractors reported.

[19] Corrected figures as previously published total included reregistrations in Utah.

[20] As reported by Bureau of Budget, and includes 7,859 cars-at-large, not allocated to any State.

Tables 2 and 3, respectively, show the accumulated increases in registration since 1921 and the annual increases expressed as a percentage of the 1921 registration for the various geographic divisions.[1] The East South Central group shows the greatest total increase, the West North Central group the least. During the year 1926 the greatest increases in proportion to the 1921 registration were in the South Atlantic and East South Central groups and the least in the West North Central, New England, and Mountain groups.

Table 4 shows the per capita wealth in the various geographic groups in 1922, and the number of motor vehicles per 1,000 of population, and numbers of persons per motor vehicle in 1921 and 1926. The groups are arranged in the order of the number of motor vehicles per 1,000 of population in 1926 and there is a very evident but not exact relation to the per capita wealth. The table shows the groups to be in the same relative order with regard to number of persons per motor vehicle that they were in 1921, except that the West South Central group has passed the New England group. The Pacific group is conspicuous as having the highest number of motor vehicles per 1,000 of population and the greatest per capita wealth.

[1] The States included in the several geographic divisions are:

New England—Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut.

Middle Atlantic—New York, New Jersey, Pennsylvania.

East North Central—Ohio, Indiana, Illinois, Michigan, Wisconsin.

West North Central—Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas.

South Atlantic—Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, District of Columbia.

East South Central—Kentucky, Tennessee, Alabama, Mississippi.

West South Central—Arkansas, Louisiana, Oklahoma, Texas.

Mountain—Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada.

Pacific—Washington, Oregon, California.

TABLE 10.—*Receipts from motor vehicle registration fees, etc., for the year 1926*

State	Total gross receipts	Subdivision of registration receipts [1]: Motor car receipts: Total from motor cars	Passenger cars and busses	Trucks and tractors	Other vehicles: Trailers	Motor cycles	Miscellaneous receipts: Dealers' license	Chauffeur and operator permits	Miscellaneous	Disposition of gross receipts: Collection and administration	For rural highway purposes: State highways	Local roads	State and county road bonds [2]	For other purposes
Alabama	$2,889,252	$2,873,119					$3,304	$9,243	$3,586	[3] $111,262	$550,760	$560,258	$1,666,835	$137
Arizona	467,795	422,490				$596	4,543	4,294	35,872	18,500	449,295			
Arkansas	3,656,368	3,611,161					5,798	23,911	15,498	73,433	1,176,405	604,367	c 1,802,163	
California	8,477,233	7,201,314	$4,528,157	$2,673,157	$245,420	37,167	45,120	285,549	662,663	[4] 1,563,533	3,721,415	3,192,285		
Colorado	1,507,379	1,455,452	1,228,841	226,611	1,209	2,588	26,738	21,108	284	75,369	716,005	716,005		
Connecticut	6,220,668	4,751,388	3,675,495	1,075,893	7,620	13,485	70,465	884,894	492,816		6,220,668			
Delaware	775,577	592,964	425,207	167,757	3,167	1,324	7,105	147,465	23,552		775,577			
Florida	6,764,468	6,702,911				5,302	33,351	16,281	6,623	122,111	4,957,406	1,684,951		
Georgia	3,381,725	3,323,296	2,769,453	553,843		3,888	41,970	6,140	6,431	119,703	3,262,022			
Idaho	1,385,930	1,343,991	1,127,940	216,051	4,190	2,415	23,895	828	10,611		143,178	1,242,752		
Illinois	14,047,208	13,108,642	9,996,135	3,112,507	57,936	20,800	91,072	370,314	398,444		8,536,365		5,510,843	
Indiana	5,093,176	4,744,318	3,683,211	1,061,107	27,233	6,899	48,100	37,395	229,231	270,307	4,822,869			
Iowa *	10,208,416									357,294	9,851,122			
Kansas *	4,803,130									247,584	2,666,828	1,888,718		
Kentucky	4,131,745	4,007,551	3,142,977	864,574		5,103	32,630	17,761	68,700	174,358	3,525,100	432,287		
Louisiana	3,993,466	3,836,324							157,142	93,508	[5] 3,845,533		54,425	
Maine	2,355,365	1,804,455	1,425,202	379,253	2,859	6,540	44,220	377,854	119,437	[6] 300,809	1,400,893		653,663	
Maryland	2,928,268	2,270,658	1,993,281	277,377	15,057	13,963	29,209	195,324	404,057	292,827	2,108,353			[7] 527,088
Massachusetts	13,077,857	10,586,446	7,134,754	3,451,692	20,011	41,675	109,666	1,527,902	792,157	1,028,834	12,049,023			
Michigan	16,953,685	15,468,556	11,647,731	3,820,825	169,568	13,274	94,462	265,733	942,092	[8] 1,207,825	9,745,860	6,000,000		
Minnesota	9,976,560	9,855,487	8,076,504	1,778,983	13,026	10,010	39,338	20,736	37,963		6,366,560		c 3,610,000	
Mississippi	1,973,412	1,966,379	1,787,310	179,069	6,435	598				59,202		1,914,210		
Missouri	7,903,025									1,391,041	2,860,049		3,651,935	
Montana	1,029,383	895,605	751,875	143,730		1,178	33,825	626	98,149	39,788		989,595		
Nebraska	3,636,097	3,463,691	2,956,116	507,575		4,103	40,299		128,004	96,575	1,062,487	2,477,035		
Nevada	209,920	209,320				410			190	13,433	64,676	131,811		
New Hampshire	1,710,905	1,343,381				8,648	26,800	240,095	91,981	95,555	1,615,350			
New Jersey	11,870,529	8,503,103	5,135,531	3,367,572	55,024	14,470	66,310	2,224,703	1,006,919	240,068	7,456,070	4,174,391		
New Mexico	513,743	490,355	487,133	3,222	2,175	600	7,250		13,363	38,020	317,149	158,574		
New York	28,786,421	25,737,573	18,064,298	7,673,275	59,815	77,418	159,652	2,367,438	384,525	2,166,001	19,581,470	4,311,830		[9] 2,727,120
North Carolina*	[10] 9,400,000									150,000	9,250.000			
North Dakota	1,578,081	1,545,586	1,354,473	191,113		1,528			30,967	280,000	649,041	649,040		
Ohio	9,818,873	1,480,246							8,338,627	([11])	4,909,437	4,909,436		([12])
Oklahoma*	5,515,045									40,000	2,166,018	3,309,027		
Oregon	6,017,759	5,814,502	4,997,783	816,719	26,324	12,513	28,913	70,968	64,539	200,000	4,363,319	1,454,440		
Pennsylvania	24,045,349	18,338,633	12,746,483	5,592,150	34,801	37,444	328,748	1,406,800	3,898,923	[13] 3,055,904	15,988,045		5,001,400	
Rhode Island	1,962,898	1,563,067	1,154,236	408,831	754	4,548	13,720	253,260	127,549	175,400	1,787,498			
South Carolina	1,951,559	1,869,961	1,588,972	280,989	16,358	824	24,085	152	40,179	176,560	1,772,180	2,819		
South Dakota	2,429,180	2,401,800	2,106,000	295,800		1,104	26,276			48,584	1,214,590	1,166,006		
Tennessee*	3,591,296									214,000	1,688,648	1,688,648		
Texas*	14,362,883										10,486,876	3,876,007		
Utah*	634,048										57,245		576,803	
Vermont	1,696,582	1,447,679	1,249,047	198,632		4,234	29,497	189,312	25,860	85,955	1,610,627			
Virginia	4,624,475	4,251,509	3,612,282	639,227	4,095	7,422	56,914	38,073	266,462	272,431	4,352,044			
Washington	6,056,003	5,472,663	4,266,572	1,205,091	39,758	14,828	87,619	431,816	9,319	[14] 649,887	4,548,424	857,692		
West Virginia	3,728,935	3,286,598	2,771,375	515,223	2,381	5,001	52,396	134,075	248,484	[15] 278,638	[16] 1,204,084		2,246,213	
Wisconsin	9,074,490	8,683,997	7,207,564	1,476,433		18,864	91,519	170,450	109,660	549,752	5,214,738	3,310,000		
Wyoming	499,878	489,371	393,899	95,472		858	9,102		547				499,878	
District of Columbia	566,312	120,728	98,986	21,742		1,327	1,906	204,122	238,229	[17] 228,160				[18] 338,152
Detailed totals [1]	231,864,509	197,336,270	([19])	([19])	815,216	402,949	1,835,817	11,944,622	19,529,635					
Grand total	288,282,352									16,602.211	191,111,302	51,702,184	25,274,158	3,592,497

[1] The States starred do not show complete receipt details and are not included in totals under first nine receipt columns, shown as detailed total.
[2] County bond payments marked (c).
[3] Includes $71,828 to probate judges.
[4] Traffic officers' expenses included.
[5] Special highway fund taken from certain county registration revenues for special roads included.
[6] State police expense included.
[7] For Baltimore streets.
[8] For expenses of branch offices and motor-vehicle theft department.
[9] New York City general fund.
[10] Conservative estimate, as data was not received.
[11] State appropriation of $326,265 omitted.
[12] A portion of local road share given to municipal corporations for street repair. Amount not stated.
[13] State highway patrol expenses of $491,770 included
[14] Highway safety fund of $431,816 included.
[15] Includes $45,801 refunds.
[16] Includes $317,011 for administration expenses of State Roads Commission.
[17] Includes $191,490 for traffic signals.
[18] For repair and construction of Washington streets.
[19] Only 33 States report details of motor-car registration receipts which total as follows: Passenger cars and busses, $133,584,823; trucks and tractors, $43,272,495 making a combined total of $176,857,318.

Tables 5 and 6 show the total number of motor vehicles manufactured, the number of those registered, the number discarded, and the percentage of the new vehicles registered which constitute replacements for the years 1921 to 1926. The motor vehicle production figures have been taken for the year ending September 30, as cars manufactured after this date do not ordinarily appear in the registration figures until the following year. In 1921 only 27 per cent of the new vehicles sold constituted replacements, but in 1926 the figure mounted to 52.2 per cent.

The annual gross receipts from motor-vehicle taxation are given in Table 7. The increase in the revenue from 1920 to 1926 has been at a somewhat greater rate than the registrations, as the average receipts per vehicle have risen from $11.10 to $13.10 during the period. The tendency toward increasing motor-vehicle fees is much more evident from 1920 to 1924 than in 1925 and 1926. The increase in the average amount per vehicle is not due entirely to increased license fee charges, but is due in part to a relatively greater increase in the number of trucks and busses which pay a high license fee.

The disposition of the gross motor vehicle tax receipts for the years 1925 and 1926 is given in Table 8. In both years close to two-thirds of the collections were allocated to State highway department funds, and if payments for interest and in sinking funds for State road bonds are added the amount is increased to nearly three-fourths. In 1926 these combined items amounted to $211,000,000. The county and other local units received for roads in 1926, including funds for payments on bonds, $57,000,000, or 19.8 per cent. Collection and administration costs amounted to 5.8 per cent in 1926 but there were nine States which paid these expenses out of other funds. Only 1.3 per cent of the collections were used for miscellaneous purposes. A portion of the amounts included under this item were allotted to general funds of counties including in their area large cities and portions of such funds were used for street work. It is evident that the motor vehicle license tax is now used almost entirely for road purposes.

GASOLINE TAXES FOR THE YEAR 1926

State	Gross tax assessed prior to deduction of refunds	Exemption refunds (deduct from gross tax)	Total tax earnings on fuel for motor vehicles [1]	Disposition of total tax earnings: Collection costs [2]	Construction and maintenance of rural roads: State highways	Construction and maintenance of rural roads: Local roads	State and county road-bond payments	Miscellaneous	Tax rates, 1926: Cents per gallon: Jan. 1	Cents per gallon: Dec. 31	Date of rate change	Net gallons of gasoline taxed and used by motor vehicles	Estimated additional gallons (not taxed) used by motor vehicles
Alabama	$2,558,651		$2,558,651	$9,582		$2,549,069			2	[3] 2		127,932,538	
Arizona	1,206,660	$228,396	978,264		$489,132	489,132			3	3		32,608,821	
Arkansas	3,785,304	200,000	3,585,304		1,991,834	684,488	[4] $908,982		4	4		89,632,594	
California	17,910,077	1,407,954	16,502,123		8,251,062	8,251,062			2	2		825,106,169	
Colorado	2,169,456	77,707	2,091,749	([5])	1,045,875	1,045,874			2	2		104,587,460	
Connecticut	2,689,372		2,689,372		2,689,372				2	2		134,468,607	
Delaware	399,309	8,895	390,414		390,414				2	2		19,520,687	
Florida	11,431,486		11,431,486	8,400	8,567,315	2,855,771			4	4		285,787,156	
Georgia	5,653,140		5,653,140	4,200	2,420,974	1,613,983		[6] $1,613,983	3½	3½		161,518,296	
Idaho	1,182,584	60,367	1,122,217	6,820	1,115,397				3	3		37,403,986	
Illinois									0	0	No tax.		650,000,000
Indiana	9,213,828	242,087	8,971,741	11,902	5,973,226	2,986,613			3	3		299,058,025	
Iowa	5,020,086	177,659	4,842,427	10,736	1,610,564	3,221,127			2	2		242,121,370	
Kansas	4,406,653	103,265	4,303,388	([7])	3,576,210	727,178			2	2		215,169,393	
Kentucky	4,935,078		4,935,078	([8])	4,935,078				3	5	Feb. 21	103,477,662	
Louisiana	2,708,567		2,708,567		2,708,567				2	2		135,428,367	
Maine	1,864,596	[9] 41,250	1,823,346	10,069	1,511,064	302,213			3	3		60,090,659	
Maryland	2,357,577	63,723	2,293,854	2,500	1,833,083			[10] 458,271	2	2		114,692,672	
Massachusetts									0	0	No tax.		280,000,000
Michigan	10,758,109	676,333	10,081,776	23,737	4,764,422	[11] 1,211,557	4,082,060		2	2		504,088,814	
Minnesota	5,072,854	268,166	4,804,688	([12])	4,804,688				2	2		240,234,382	
Mississippi	[13] 4,088,200		4,088,200	3,150	1,940,186	1,990,912	[14] 50,727	[13] 103,225	3	4	Apr. 1	105,887,426	
Missouri	5,777,163	116,018	5,661,145	54,698	5,606,447				2	2		283,057,270	
Montana	870,712		870,712		131,002	477,707		[6] 262,003	2	[15] 2		43,535,576	
Nebraska	3,055,705	15,778	3,039,927	7,028	3,032,899				2	2		151,996,357	
Nevada	433,820	28,002	405,818		202,909	202,909			4	4		10,145,454	
New Hampshire	781,453	12,871	768,582		768,582				2	2		38,429,100	
New Jersey									0	0	No tax.		255,000,000
New Mexico	762,851		762,851	25,428	737,423				3	3		25,428,358	
New York									0	0	No tax.		720,000,000
North Carolina	8,113,044	326,571	7,786,473		[16] 7,786,473		([16])		4	4		194,661,825	
North Dakota	1,083,531	95,038	988,493		820,101			[6] 168,392	1	2	July 31	73,689,462	
Ohio	13,556,253	298,987	13,257,266		5,965,770	3,314,316		[17] 3,977,180	2	2		662,863,296	
Oklahoma	6,237,989	[18] 25,580	6,212,409	([19])	4,141,606	2,070,803			3	3		207,080,296	
Oregon	3,536,142	202,313	3,333,829	7,693	3,326,136				3	3		118,493,937	
Pennsylvania	[20] 11,781,782		11,781,782		8,709,213	2,903,071		[6] 169,498	2	2		588,379,021	
Rhode Island	629,024	117,128	511,896	([21])	511,896				1	1		51,189,641	
South Carolina	4,505,694	8,726	4,496,968	([21])	2,698,181	1,798,787			5	5		89,939,352	
South Dakota	2,284,761	360,003	1,924,758		1,924,758				3	3		64,158,589	
Tennessee	3,852,524		3,852,524	38,525	3,813,998				3	3		128,417,453	
Texas	5,228,009	1,123	5,226,886		3,920,164			[22] 1,306,721	1	1		522,688,578	
Utah	1,258,009		1,258,009	3,750	1,057,159		197,100		3½	3½		35,943,117	
Vermont	553,093		553,093	([23])	553,093				2	2		27,654,594	
Virginia	6,158,124	302,454	5,855,670	[24] 697	3,903,316	1,951,657			3	4½	Mar. 11	135,814,061	
Washington	3,701,676	219,583	3,482,093	([25])	3,482,093				2	2		174,104,636	
West Virginia	3,001,131	78,456	2,922,675	([26])	2,922,675		([27])		3½	3½		83,504,998	
Wisconsin	5,373,667	163,862	5,209,805	9,982	2,238,574	2,961,250			2	2		260,490,262	
Wyoming	571,449	2,860	568,589		568,589				2½	2½		22,743,572	
District of Columbia	1,020,050	4,857	1,015,193					[28] 1,015,193	2	2		50,759,671	
Total			187,603,231	238,897	129,441,520	43,609,479	5,238,869	9,074,466	Av.	2.38		7,883,983,560	1,905,000,000

[1] The net tax after deduction of refunds for exemptions according to law and represents the actual taxes available for disposal. The first 2 columns show only the procedure and are not totaled.

[2] Collection costs in many States are paid from other State funds, and when amounts and sources are reported notes are entered below.

[3] Changed to 4 cents on Jan. 4, 1927.

[4] Allotted by appropriation out of gasoline tax fund, but claims exceed this by $225,000.

[5] Collection costs charged to State controllers office fund.

[6] For State general treasury fund.

[7] Paid $8,750 from general revenue of State.

[8] From general State fund.

[9] Refund of 2 cents only, allowed by law.

[10] For maintenance of Baltimore Streets.

[11] State rewards to counties.

[12] Paid from oil inspection appropriation.

[13] Includes $103,225 from extra 2-cent tax collected from Harrison County for sea wall to protect State highway in this county.

[14] Sea-wall bonds.

[15] Changed to 3 cents on January 1, 1927.

[16] Large part of State highway share is paid for interest and sinking fund on State highway bonds.

[17] For repair and maintenance of municipal streets.

[18] Deduction of 3 per cent allowed for evaporation.

[19] Paid $17,616 from State funds.

[20] Includes $14,202 from delinquent 1 cent tax due in 1921–1923.

[21] State appropriation of $5,000.

[22] For free school fund.

[23] Collection cost of $500 from motor vehicle bureau appropriation.

[24] Only part of cost, remaining cost of $5,803 is from State appropriation.

[25] From Motor vehicle license fund, $5,000.

[26] State appropriation of $7,500.

[27] State road bond payments taken from gasoline tax, amount not reported.

[28] For Washington Streets.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1924.
Report of the Chief of the Bureau of Public Roads, 1925.
*Report of the Chief of the Bureau of Public Roads, 1926. 5c.

DEPARTMENT BULLETINS

No. 105D. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
*136D. Highway Bonds. 20c.
220D. Road Models.
257D. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
*314D. Methods for the Examination of Bituminous Road Materials. 10c.
*347D. Methods for the Determination of the Physical Properties of Road-Building Rock. 10c.
*370D, The Results of Physical Tests of Road-Building Rock. 15c.
386D, Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387D. Public Road Mileage and Revenues in the Southern States, 1914.
388D. Public Road Mileage and Revenues in the New England States, 1914.
390D. Public Road Mileage and Revenues in the United States, 1914. A Summary.
407D, Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
*463D, Earth, Sand-Clay, and Gravel Roads. 15c.
*532D. The Expansion and Contraction of Concrete and Concrete Roads, 10c.
*537D. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests, 5c.
*583D, Reports on Experimental Convict Road Camp, Fulton County, Ga. 25c.
*660D, Highway Cost Keeping. 10c.
*670D. The Results of Physical Tests of Road-Building Rock in 1916 and 1917. 5c.
*691D. Typical Specifications for Bituminous Road Materials. 10c.
*724D. Drainage Methods and Foundations for County Roads. 20c.
*1077D. Portland Cement Concrete Roads. 15c.
*1132D. The Results of Physical Tests of Road-Building Rock from 1916 to 1921, Inclusive. 10c.
*1216D. Tentative Standard Methods of Sampling and Testing Highway Materials, Adopted by the American Association of State Highway Officials and Approved by the Secretary of Agriculture for Use in Connection with Federal aid Road Construction. 15c.

DEPARTMENT BULLETINS—Continued

No.1259D. Standard Specifications for Steel Highway Bridges, adopted by the American Association of State Highway Officials and approved by the Secretary of Agriculture for use in connection with Federal-aid road work.
1279D. Rural Highway Mileage, Income, and Expenditures, 1921 and 1922.

DEPARTMENT CIRCULARS

No. 94C. TNT as a Blasting Explosive.
331C. Standard Specifications for Corrugated Metal Pipe Culverts.

MISCELLANEOUS CIRCULARS

No. *60M. Federal Legislation Providing for Federal Aid in Highway Construction. 5c.
62M. Standards Governing Plans, Specifications, Contract Forms, and Estimates for Federal Aid Highway Projects.

FARMERS' BULLETINS

No. *338F. Macadam Roads. 5c.
*505F. Benefits of Improved Roads. 5c.

SEPARATE REPRINTS FROM THE YEARBOOK

No *739Y. Federal Aid to Highways, 1917. 5c,
*849Y, Roads. 5c.
914Y, Highways and Highway Transportation.

OFFICE OF PUBLIC ROADS BULLETIN

No. *45, Data for Use in Designing Culverts and Short-Span Bridges. (1913.) 15c.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH

Vol. 5, No. 17, D- 2. Effect of Controllable Variables upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 24, D- 6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced-Concrete Slabs Under Concentrated Loading.
Vol. 10, No. 5, D-12. Influence of Grading on the Value of Fine Aggregate Used in Portland Cement Concrete Road Construction.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric centrated Loads.

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* Department supply exhausted.

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

STATUS OF FEDERAL AID HIGHWAY CONSTRUCTION

AS OF

MARCH 31,1927

STATES	FISCAL YEARS 1917-1926			FISCAL YEAR 1927									BALANCE OF FEDERAL AID FUND AVAILABLE FOR NEW PROJECTS	STATES
	PROJECTS COMPLETED PRIOR TO JULY 1, 1926			PROJECTS COMPLETED SINCE JUNE 30, 1926			*PROJECTS UNDER CONSTRUCTION			PROJECTS APPROVED FOR CONSTRUCTION				
	TOTAL COST	FEDERAL AID	MILES	TOTAL COST	FEDERAL AID	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES		
Alabama	$ 18,226,411.34	$ 8,725,985.09	1,298.3	$ 1,834,960.34	$ 889,114.85	101.9	$ 6,553,665.00	$ 3,120,971.51	381.3	$ 42,206.64	$ 21,103.32	2.3	$ 3,139,500.23	Alabama
Arizona	10,949,878.25	5,863,772.36	729.8	623,444.90	426,049.45	39.7	1,281,975.69	874,757.16	81.9				3,509,664.04	Arizona
Arkansas	18,364,544.50	7,666,698.35	1,323.0	3,566,911.33	1,659,719.92	206.3	2,301,986.68	1,106,933.82	203.3	1,329,872.25	664,576.12	50.5	1,785,771.79	Arkansas
California	27,142,596.90	13,003,592.30	1,058.0	6,941,359.95	3,451,010.85	231.2	8,208,678.63	3,820,929.86	162.3				4,280,718.99	California
Colorado	13,905,904.64	7,127,288.18	745.0	1,416,916.01	715,537.14	66.8	5,821,868.38	2,857,490.23	268.7	798,158.04	367,739.24	26.8	2,634,277.21	Colorado
Connecticut	5,414,567.19	2,100,585.80	117.1	684,812.28	245,719.74	13.6	5,427,221.54	1,444,820.58	69.8	472,653.97	234,096.57	1.1	781,153.31	Connecticut
Delaware	4,918,052.29	1,781,665.60	124.3	1,038,483.07	452,067.18	28.0	591,038.05	241,755.90	17.6	283,393.43	129,565.50	14.7	234,628.82	Delaware
Florida	3,832,680.26	1,824,362.32	132.9	3,644,176.05	1,803,550.28	112.2	7,664,734.36	3,372,923.19	179.8	957,489.91	359,552.23	24.5	1,624,016.98	Florida
Georgia	24,791,206.97	11,664,237.86	1,794.0	4,935,761.11	2,421,299.18	280.5	9,362,594.41	4,579,562.93	422.9	779,932.01	382,640.04	2.6	1,363,421.99	Georgia
Idaho	11,061,198.14	5,882,112.70	724.7	1,966,337.13	1,075,121.31	103.7	2,307,369.93	1,442,803.06	169.4	418,539.37	246,879.31	23.0	847,903.63	Idaho
Illinois	44,116,611.86	20,619,995.74	1,377.7	4,022,370.94	1,971,173.14	137.8	8,655,416.51	4,123,404.18	310.0	4,221,388.28	2,110,694.14	151.1	4,161,359.80	Illinois
Indiana	16,949,425.87	8,172,125.19	534.3	4,410,029.48	2,117,281.93	147.3	16,141,158.54	7,546,819.61	448.8	3,012,000.00	1,501,000.00	106.7	793,900.27	Indiana
Iowa	29,062,375.40	11,926,302.10	2,114.8	4,503,982.56	2,101,069.80	298.1	11,062,347.04	5,323,126.12	554.3	4,546,398.59	1,878,372.08	123.2	301,691.90	Iowa
Kansas	32,826,601.64	12,590,489.25	1,160.6	3,144,506.10	1,467,396.11	247.6	13,296,288.06	5,254,390.81	668.7	1,229,342.16	483,802.72	80.3	1,736,864.11	Kansas
Kentucky	20,737,706.10	8,432,082.25	758.3	2,245,656.73	916,591.56	100.1	8,053,911.85	3,868,025.81	365.3	1,652,298.13	789,867.06	79.7	566,189.33	Kentucky
Louisiana	13,830,592.68	6,144,739.99	1,065.9	1,528,857.84	691,095.79	77.0	4,499,026.24	2,125,856.09	183.1	141,920.37	69,698.88	3.6	1,254,325.25	Louisiana
Maine	8,747,552.76	4,192,507.39	303.6	1,817,247.30	665,945.28	54.0	2,231,038.93	821,344.43	63.4	87,912.01	43,956.00	5.6	1,421,868.90	Maine
Maryland	10,924,943.10	5,112,991.22	423.3	688,351.18	334,258.01	46.0	1,006,990.82	455,368.54	42.4				657,558.23	Maryland
Massachusetts	18,353,757.71	6,657,260.62	374.5	936,137.25	332,778.92	10.0	5,129,237.10	1,353,705.79	78.6	1,333,518.06	377,019.05	24.7	2,477,061.62	Massachusetts
Michigan	25,997,240.78	11,827,052.30	963.0	2,813,653.04	1,245,647.96	74.3	13,620,576.62	6,139,469.44	383.3	1,983,924.00	943,575.00	51.5	2,401,311.30	Michigan
Minnesota	37,170,985.95	15,586,116.56	3,181.9	7,928,662.52	3,460,029.11	461.6	4,356,315.57	1,301,198.90	285.7	3,029,628.65	786,600.00	131.6	578,576.43	Minnesota
Mississippi	15,146,088.52	7,414,534.10	1,129.0	1,366,914.56	680,646.71	89.5	7,731,758.49	3,768,345.62	399.3	1,024,955.07	463,130.74	60.3	1,109,239.83	Mississippi
Missouri	28,989,166.92	13,736,014.86	1,543.2	10,387,573.10	4,558,081.01	310.5	11,340,772.60	4,576,500.41	302.3	1,760,794.05	778,083.54	97.8	1,544,931.19	Missouri
Montana	11,400,983.81	6,333,465.89	1,054.9	1,454,011.91	853,822.80	96.7	1,549,479.24	1,333,488.24	122.1	881,460.12	473,618.96	101.8	5,881,988.11	Montana
Nebraska	11,533,401.62	5,474,202.52	1,768.3	3,734,684.55	1,837,751.60	395.2	11,471,106.22	5,649,467.81	1,200.4	1,197,420.91	582,033.94	55.2	2,676,917.13	Nebraska
Nevada	7,558,195.51	5,130,934.59	538.8	2,731,465.04	2,351,683.67	300.5	1,277,869.71	1,101,359.39	157.6	356,289.12	312,536.81	39.4	847,210.54	Nevada
New Hampshire	4,992,558.60	2,377,450.07	237.6	846,458.09	386,537.45	26.4	647,214.00	303,802.51	18.7				467,326.97	New Hampshire
New Jersey	16,346,301.01	5,098,342.21	290.3	5,881,939.07	2,397,022.27	26.0	4,500,662.42	855,223.56	54.9	770,916.35	232,455.00	15.5	818,987.96	New Jersey
New Mexico	12,404,337.77	7,339,657.38	1,427.0	624,964.75	386,992.83	56.2	2,720,791.07	1,981,847.17	237.4	495,938.47	389,782.29	7.9	2,060,869.33	New Mexico
New York	43,224,279.79	17,911,957.19	1,197.0	6,770,793.12	3,052,682.04	196.6	36,107,773.00	9,031,203.95	562.9	6,432,733.00	1,485,877.50	83.2	6,198,791.32	New York
North Carolina	27,009,419.47	11,177,337.94	1,259.9	7,601,626.14	3,041,570.47	180.7	2,640,140.66	1,257,610.68	79.7	838,141.60	380,630.34	20.1	1,593,412.57	North Carolina
North Dakota	12,313,311.40	6,031,858.78	2,193.1	3,472,543.67	1,669,801.95	506.1	4,479,653.02	2,469,693.22	658.7	1,273,245.36	636,475.82	84.1	1,135,779.23	North Dakota
Ohio	47,699,532.90	17,371,787.03	1,364.1	4,552,216.29	1,832,932.11	145.5	11,559,782.42	4,459,726.00	331.8	825,886.06	276,998.22	16.2	4,552,561.64	Ohio
Oklahoma	29,247,950.33	13,159,999.15	1,178.9	1,679,658.40	758,973.69	62.3	3,462,134.01	1,464,462.31	210.1	1,891,842.75	720,320.96	114.0	1,707,921.89	Oklahoma
Oregon	17,027,878.42	8,593,214.79	939.2	1,937,991.20	1,156,191.52	97.1	2,560,829.16	1,362,564.70	66.4				949,577.99	Oregon
Pennsylvania	61,366,150.80	21,560,732.04	1,188.8	10,699,570.21	3,119,354.44	226.8	19,029,021.20	5,498,861.46	379.8	3,080,400.33	1,128,788.64	66.5	3,366,779.42	Pennsylvania
Rhode Island	3,988,616.09	1,558,829.06	86.7	1,244,797.29	439,650.00	29.3	778,986.12	205,665.00	13.7	239,059.07	74,175.00	5.0	754,874.94	Rhode Island
South Carolina	15,020,639.90	6,766,322.93	1,481.9	1,873,240.10	711,909.31	75.3	5,591,271.61	2,314,982.64	210.0	930,746.72	227,507.31	31.9	835,790.81	South Carolina
South Dakota	17,468,373.19	8,603,826.97	2,181.2	1,528,975.74	765,573.81	261.5	3,256,707.54	1,708,377.00	571.4	465,885.59	224,609.71	72.2	1,084,466.51	South Dakota
Tennessee	21,624,631.57	10,276,584.02	780.0	2,470,439.14	1,183,577.64	78.5	8,417,516.83	3,519,005.07	235.6	111,887.73	35,000.00	.3	1,881,190.27	Tennessee
Texas	69,183,673.48	27,440,254.72	4,920.2	7,052,011.25	3,231,149.65	438.4	16,686,487.66	7,440,666.31	613.8	1,694,198.26	813,238.16	68.7	6,178,394.16	Texas
Utah	8,253,178.03	5,098,440.68	846.4	901,199.30	668,639.27	82.5	2,235,093.98	1,701,800.30	161.9	129,047.06	91,454.82	11.6	1,105,649.93	Utah
Vermont	4,242,042.64	2,017,699.51	134.5	631,574.99	266,003.78	13.1	1,636,808.55	618,603.78	30.0				731,824.93	Vermont
Virginia	21,990,249.44	10,385,728.11	1,005.5	3,922,621.16	1,736,445.95	128.4	4,992,161.42	2,094,951.29	125.8	1,660,690.47	571,492.05	33.5	155,610.60	Virginia
Washington	17,078,511.63	7,782,909.46	668.6	1,105,994.34	463,642.49	42.5	3,690,460.86	1,750,600.00	68.2				1,280,156.05	Washington
West Virginia	9,473,716.44	4,141,062.65	392.9	951,130.88	432,685.36	26.5	6,462,740.28	2,640,353.04	204.2	780,098.38	348,827.13	39.7	583,218.82	West Virginia
Wisconsin	24,856,508.19	10,392,706.73	1,592.1	2,623,423.79	1,251,529.42	119.9	6,558,615.95	3,141,955.09	297.7	2,974,286.62	1,392,816.00	71.7	3,130,263.76	Wisconsin
Wyoming	10,928,302.56	6,040,887.05	1,133.5	1,594,423.97	1,016,214.00	172.5	1,758,366.53	1,110,813.63	114.1	65,821.31	42,256.00	16.7	1,290,472.32	Wyoming
Hawaii				343,664.15	97,440.00	6.5	1,439,661.16	464,352.64	23.1	346,662.73	98,010.00	6.6	805,975.36	Hawaii
TOTALS	966,692,834.36	426,178,703.58	52,526.6	152,686,512.30	68,889,861.74	7,029.7	321,155,105.65	135,001,640.77	12,762.0	56,549,982.02	23,147,846.20	2,023.4	91,281,947.71	TOTALS

* Includes projects reported completed (final vouchers not yet paid) totaling: Estimated cost $81,673,243.27 Federal aid $ 34,552,347.62 Miles 3,129.6